STUDIES ON THE FERTILITY OF EGYPTIAN SOILS

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B.Sc.,Hons.(Edinburgh) Oct. 1923.

Thesis submitted for the degree of

DOCTOR OF SCIENCE

of

the University of Edinburgh.

Edinburgh.
April, 1950.

Explanatory Note by Candidate concerning the Work carried out, published and submitted in the Thesis.

I held the post of Senior Chemist in the Chemical Section of the Ministry of Agriculture, Egypt for nineteen years from February 1930. During the greater part of that time I was in charge of that branch of the Section responsible for investigations into soil conditions and into the manuring of the main agricultural crops. The results of these investigations form the subject matter of the publications submitted, of which a numbered list is attached. They were written entirely by me, with the exception of the Foreword to No. 1 which was written by Dr. Balls and of No. 5 which was written jointly with him. As a soil chemist in Egypt, I was in effect presented with a unique opportunity of initiating and continuing combined field and laboratory observations on an adequate scale for sufficient periods of time, and the published accounts illustrate the use that I made of it.

On first arrival in Egypt I found that field trials of varied description and utility on the effect of manures were being carried out by the Agronomic Section of the Ministry of Agriculture partly for their own account and partly for that of the Chemical Section, with the latter at the same time conducting some additional ones on a much more limited scale; this resulted in a minimum of useful information for the effort involved. By agreement with Hussein Enan, then Sub Director of the Agronomic Section, these various trials were replaced by a uniform series of experiments with each crop to be carried out exclusively by the Agronomic Section. The importance of having accurate information on yield in connection with investigations into soil fertility and into the effect of fertilisers can scarcely be exaggerated. It can only be obtained from properly designed field experiments which are sufficiently numerous and well distributed throughout the country as to be representative of the crop being dealt with;

the emphasis is on the number of observations and the length of time during which they are continued. The adoption of such a scheme offered the best prospect for economic advance. The design and instructions for these experiments were drawn up in the Chemical Section according to my directions and the results worked out there either by myself or under my close supervision. A beginning was made with the cotton crop in 1931; maize experiments followed in 1932; those with wheat and barley were begun in 1935, with rice in 1937, while the scheme was extended to include berseem and beans in the autumn of 1940.

This arrangement about the field experiments lasted only so long as Hussein Enan Pasha remained in the Ministry of Agriculture (he became in succession Director of the Agronomic Section, Under Secretary of State, and Minister); it came to an end when he left it in the end of 1946. It is the reason why his name appears on the cotton bulletins (Nos. 2 and 9).

The occasion of the writing of the bulletin (No. 5) on dibble-sowing was provided, almost as a side-line, from the 1938 manurial experiments with cotton by the incidental demonstration (Fig. 14) of the essentials for success with the method. The bulletin was a joint effort by Dr. Balls and myself but that part of it from pages 12 to 24 as well as the figures in the appendix were exclusively contributed by me from the Chemical Section. At the time it was written Dr. Balls had become Chief Cotton Technologist after having been Chief Botanist; he never had any official connection with the Chemical Section.

The question of the evaluation of nitrogenous fertilisers (No. 7) arose during the war when Dr. Balls was Chairman of the Scientific Committee for the Middle East. The material for the appraisement was provided in the Chemical Section from the results (response curves) of the field experiments or extracted from the Annuaire Statistique (areas and average yields). I actually wrote the bulletin in the summer of 1947 when Dr. Balls had already retired from the Egyptian Government service; he made minor corrections and provided the summary, before it went to the press.

Fahmy Khalil's contribution to the statistical bulletin (No. 7) lay in his knowledge of Egyptian Agriculture and in the assistance he gave in extracting the data on which it is based. He gave assistance of a similar nature in connection with the first publication (No. 2 on the list) on the cotton experiments but his main contribution has been in connection with estimations of available phosphoric acid (by Aspergillus niger) and of available nitrogen. Once the details of the methods used had been established for Egyptian conditions, their routine application was carried out either by Khalil himself (Aspergillus niger) or under his immediate supervision (available nitrogen). He gave me similar assistance in the preparation of the material for the organic matter bulletin (No.4) as with the first cotton bulletin (No.2). The help he gave with the data for the phosphoric acid bulletin (No.8) was very much less, while for the continuation of the analysis of the cotton experiments (No.9) his contribution was negligible compared, for example, with that of Mohammed Abou el-Fadl, to whom acknowledgement is made on page 66, so that I omitted his name altogether.

The bulletin on soils (No.1) contains the record of part of the most fundamental work that has been done. I began the collection of the material for it within a week of arriving in Egypt, with the assistance of Mahfouz Rizk. The details of the analytical methods used were established by me before they were used by the others, always excepting the clay fusions, which I did with some assistance from Mahfouz Rizk alone.

The most comprehensive account of the work that has so far appeared is contained in the cotton bulletin (No.9) which is last on the list; it is in some sort the outcome of the ones that go before it. I have written a simplified summary of its contents in two parts for the Empire Cotton Growing Review, in which it is appearing in the April and July numbers of this year.

LIST OF PUBLICATIONS SUBMITTED

1. "The Nature of Soil Deterioration in Egypt" by David S. Gracie, Mahfouz Rizk, Ahmed Moukhtar and Abdel Hamid I. Moustafa.
Bull., No. 148 Technical and Scientific Service, Ministry of Agriculture, Egypt. (1934).

2. "An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt" by David S. Gracie and Fahmy Khalil in collaboration with Hussein Enan.
Bull., No. 152 Technical and Scientific Service, Ministry of Agriculture, Egypt (1935).

3. "Les effets du sol, de la season et de la fumure sur la vegetation et le rendement du Cotonnier"
Bulletin de l'Union des Agriculteurs d'Egypte, Mars 1939, No. 301.
Translation (by R. Aladj~~ur~~em) of a lecture given by D. S. Gracie to the members of the Real Estate Association for Egypt in Alexandria on the 14th March, 1939.

4. "The Quantity, Distribution and Composition of the Organic Matter and Available Nitrogen in Egyptian Soils" by David S. Gracie and Fahmy Khalil. Bull., No. 222 Technical and Scientific Service, Ministry of Agriculture, Egypt (1939)

5. "Dibble-Sowing of Cotton Methods, Effects and Profits" by David S. Gracie and W. Lawrence Halls.
Bull., No. 229 Technical and Scientific Service, Ministry of Agriculture, Egypt (1939)

6. "The Organic Content of Soils of the Middle East" by David S. Gracie.
Proceedings of the Conference on Middle East Agricultural Development, p. 107, (1944)

7. "Evaluating the Effects of Nitrogenous Fertilisers by combining Statistical and Agronomic Data" by W. Lawrence Balls, David S. Gracie and Fahmy Khalil.
Bull., No. 249 Technical and Scientific Service, Ministry of Agriculture, Egypt (1948)

8. "The Total and Available Phosphoric Acid in Egyptian Soils and the Effect of Superphosphate on the Main Agricultural Crops" by David S. Gracie and Fahmy Khalil. Bull. No. 251 Technical and Scientific Service, Ministry of Agriculture, Egypt (1948)

9. "An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt. (Continued) by David S. Gracie in collaboration with Hussein Enan. Bull. No. 152 Technical and Scientific Service, Ministry of Agriculture, Egypt (1949)

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service
(Chemical Section)
BULLETIN No. 148

THE NATURE OF SOIL DETERIORATION IN EGYPT

BY

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WITH FOREWORD BY

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(Recommended for publication by the Publications Committee of the Ministry of Agriculture, which is not, as a body, responsible for the opinions expressed in this Bulletin)

Govt. Press, Bulâq, Cairo, 1934

Government Publications are on sale at the "Sale Room," Ministry of Finance. Correspondence relating to these publications should be addressed to the "Publications Office," Government Press, Bûlâq, Cairo.

Price - - - - - - - - P.T. 4

FOREWORD

BY

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The development of perennial irrigation was long ago observed to cause "salting" of land adjacent to high level canals in a way which seemed to be explicable on simple physical interpretations (Willcocks, *e.g.*). Recent and more intimate study of such infiltrated areas has shown that this explanation is too simple and that the infertility can be of a different type which is characterised by *impermeability to water* and is not necessarily even recognisable by accumulation of salt. At present no means of reclamation is known; the full process of formation must be learned in order to reverse it.

It must be understood that impermeability is developed only at particular levels in the soil profile, where the equilibrium conditions necessary for its formation have existed. This may be at any level and its thickness also varies. But such impermeable layers affect crop-root development anywhere within three metres of the surface; in the top at 20 centimetres they stop cultivation of berseem, at 30 centimetres they spoil rice, while at deeper levels they affect the deeper rooted plants at successively later stages of development.

Secondary or ordinary "salting" may take place in the superincumbent soil by simple physical causation, as in an evaporating basin. The Giza farm had five times as much sodium chloride in its sub-soil water in 1933 as it had at the sample places and at the same depth in 1913, two years after the canals on its margin were converted to perennial flow in 1911. As yet it is fully fertile, though isolated salty patches have been seen to develop suddenly.

Such changes in the soil profile are definitely related to movements of under-ground water, and so are related to the intensely variable surface geology of the fluviatile deposits which make and underly the soil of Egypt. In the simplest case these changes take place adjacent to the high-level canals, but an under-ground waterway in a sand-bed may cause formation at a distance, and—since the chemical changes involved are sequential—at a later time. A detailed study of the movements of the water-table at Giza has been followed by continuous observation of the composition of the water, which has demonstrated these changes in space and in time to be unexpectedly great and various.

Thus the original sudden deterioration of localised patches is being succeeded by slow extension of these patches in a different type of deterioration, and by the appearance of new ones, like spots on the face of Egypt.

There is reason to think that this formation of infertile (alkali) soils is a bye-product of a sequence of events which begins with the activity of sulphate-reducing bacteria alternating with the reverse action of bacteria which oxidise sulphides.

The first clues were given by Templeton and Zaghloul's (International Botanical Congress, Cambridge, 1931) observation of the formation of deep blue zones round roots immersed in the water-table. It has been extended by examination of clay structures in deep bores, down to 50 metres, as a continuous chain of events culminating in the formation of geological deposits of iron pyrites.

Related earlier observations were those of Hughes on an iron pan under a rice field. Also a soil sample (Aladjem) from the margin of a rice field in the "barari" lands of North Egypt, which contained 34 % of free sulphur.

Re-aeration of Tempelton and Zaghloul's blue stains, whether these are localised in the reduction gradient round a respiring root or spread through the long waterlogged soil apparently uniformly, is followed by oxidation of the ferrous sulphide and (round the root) by the formation of agate-like zones of brown tints resembling a periodic precipitation of ferric oxide. These colour changes show that the iron is transported bodily, and must therefore pass at certain stages through a soluble phase (such as sulphate) as well as existing insolubly as hydrated oxides and sulphides.

Deposition of crystalline calcium carbonate may also take place under certain conditions forming such root-fossils as a tube of iron oxide mixed with calcite, which tube is lined by the outer cortex of the root, while the centre is filled with large calcite crystals. Or the tube itself may be of calcite only. The gypsum veins characteristic of lake floor mud are probably partly such root-pseudomorphs, and partly amorphous deposits of gypsum accumulating as a result of variations in the oxygen gradient round rotting debris and animal remains.

The chemical sequence of events is still vague but it is a reasonable assumption that the sulphur-iron-oxygen-carbon system is readily capable of producing all these structures when passing through phases of reduction (waterlogged) or oxidation (drained), with infertile soils as a byeproduct contingent on alterations in the composition of the water.

The profile details in any given soil will depend on its overhead water supply, its underground water supply, the chemical composition of both (chiefly the latter in practice), and on the primary structure of the soil (sand and clay strata) together with the secondary changes induced therein.

The implication of these observations combined from geology, hydrology, soil science, plant physiology and bacteriology are severely practical. These localised deteriorations are still continuing, and will continue until all the soils in Egypt which are so situated as to be capable of such modification have been thus modified. A process which may take centuries.

There must be a remedy applicable to soil which has already deteriorated, obtainable by reversing the process when we know the whole chain of events in detail. Meanwhile, and even concurrently, there can be preventive measures ; the first link in the chain is the activity of sulphate-reducing bacteria under water-logged conditions, and primary water-logging due to the rise of the Nile can no more be prevented than the bacteria can be annihilated. But primary water-logging has existed for some six thousand years. Secondary water-logging on the other hand is a recent innovation, and it is preventable, at a price, as in other countries, by lining the high-level canals. Thirdly the lateral flow of dangerously modified under-ground water can be rendered innocuous by field drainage.

Drainage in Egypt thus assumes a new aspect. It is not merely concerned with the direct effects of water-logging on the roots of crops, as in the pre-war epoch, nor is it merely a cure for this trouble, nor for the reclamation of the deteriorated soil. It becomes an operation to be undertaken for preventive purpose, while the big government drains recede into their proper perspective as mere collectors for the water extracted from the individual feddan through invisible lines of tile-drains.

INTRODUCTION

During the past few years an intensive study of cases of soil deterioration has been made by Mr. D.S. Gracie and other members of the staff of the Chemical Section. Full details of this study will be published later, but, in view of the urgency and gravity of the situation, it has been considered advisable to ask Mr. Gracie to write a preliminary account in order to draw attention to this important question.

It is hoped that this bulletin will reach a very wide public in Egypt, some of whom may not be conversant with modern methods of soil investigation. It may not be out of place, therefore, to give a brief outline of some of these methods.

In recent years a considerable impetus has been given to soil studies by the introduction of (*a*) the conception of the soil profile, (*b*) the method of estimating exchangeable bases and (*c*) investigations into the nature of the clay complex itself.

The whole succession of layers shown by a soil in section is known as the " soil profile " and it is of the utmost importance that samples for laboratory examination should be taken in the field according to the differences met with in the profile. Thus, an inspection of the tables of analyses given in the appendix will show that the layers of soil sampled are not always of the same depth, that is, they were not chosen arbitrarily, but were determined by variations observed in the soil profile. The accuracy of the sampling can be gauged by the sudden changes shown at certain depths in the content of some of the soil constituents. Such observations would have been altogether missed if sampling had been done at arbitrary depths ; further, examination of the surface soil alone could not possibly have produced the results described.

With modern soil analysis it is possible to classify the constituents more closely according to the forms in which they actually exist in the soil than was possible in the past. Thus bases like calcium and magnesium may exist in the soil in the following states:

(*a*) as components of soluble salts, extractable with water;

(*b*) as carbonates, removable by means of dilute acids;

(*c*) as " exchangeable bases ", that is, in combination mainly with the clay of the soil from which they can be removed or exchanged by treating the soil with a solution of a salt such as sodium chloride, whereby the sodium of the salt takes the place of the calcium or magnesium in the clay or is " exchanged " for them. The process is the reverse of what takes place in a permutite or zeolite water-softening plant.

(*d*) as part of the clay-complex, in which condition their estimation depends on the disintegration of the clay by means of strong acids or fusion with sodium carbonate.

It should be emphasised that in previous work of this nature on Egyptian soils (Mosseri and Hughes) undertaken from a practical point of view attention was restricted to the estimation of the water-soluble constituents (chloride, carbonate, bicarbonate etc.). In the public mind even today such estimations are still regarded as being all that is necessary to characterise infertile soils. From the point of view developed in this bulletin the quantity of chloride, carbonate and bicarbonate are mere reflections of more fundamental alterations in the nature of the soil.

A complete study of a soil, therefore, requires: (1) that careful field observations should be made, (2) that all the layers in the profile should be sampled and (3) that in the analysis of the samples all the constituents should be classified according to such a scheme as is illustrated above. When this is done the results of the laboratory examinations can be correlated with the properties exhibited by the soil in the field. Then, particularly in Egypt, where the soils in most cases contain a high proportion of clay, the most fundamental factor determining these properties is the actual composition of the clay-complex. Of critical importance also is the relative proportions of the exchangeable bases associated with the clay. These bases, although small in total amount, have a material effect on the properties of the clay, according to the nature of the dominating one, that is to say, whether calcium or magnesium or sodium is present in the highest proportion. The amount and the kind of soluble salts present is also useful in discriminating the type of soil deterioration.

The alterations in the chemical composition demonstrated in the cases of deterioration studied show that they have been brought about primarily by the rise of sub-soil water, and the direct relation of this to soil deterioration is established in a very clear manner and from an entirely new point of view.

Recognition of the necessity for preventing the rise of sub-soil water in perennially irrigated land is not new. It was realised long ago and general drainage advocated on the one hand by irrigation engineers such as Sir Colin Scott-Moncrieff, Sir William Willcocks, Mr. E.W. Percival Foster and others and on the other hand by scientific workers like Dr. W. Lawrence Balls, Messrs. A. Lucas, F. Hughes, H.T. Ferrar and C. Audebeau Bey. Although most people today are agreed as to the necessity of drainage in certain places, its general application to perennial areas is still a subject of controversy. Twenty-four years ago the controversy raged largely around the question of the failure of the cotton crop. Will it now be shifted to the " failure " of the soil itself ?

At that time, in reply to the argument that the cost of drainage was prohibitive, it was said : " It will require a very large sum to make the saving of the cotton crop too expensive ". (E.W. Percival Foster). Today, although vast sums of money have been spent and valuable work done in the provision of main and subsidiary drains, much more will be necessary. It will require a very much larger sum to make the saving of the soil of Egypt " too expensive ".

W. T. H. Williamson.

Chief chemist.

MINISTRY OF AGRICULTURE, EGYPT

The Nature of Soil Deterioration in Egypt

The following is a preliminary account of the causes and nature of the deterioration of *fertile Egyptian soils*. It is based on evidence obtained in cases where the owner or occupier had reason to complain about the unsatisfactory condition of the whole or part of his land. Since these complaints were entirely spontaneous the state of affairs revealed by their investigation must be taken as a fair sample of the actual conditions throughout the country. The problems encountered in the reclamation of the salty lands in the North of the Delta are not necessarily the same as those dealt with here.

The investigations into soil conditions in Egypt, the results of which are outlined below, originate in the almost universal replacement of the basin system of irrigation by, very largely, free flow perennial irrigation. From the point of view of the soil itself it has frequently been pointed out that the essential feature distinguishing basin from perennial irrigation is drainage. Good drainage, *i.e.* aeration of the soil and the prevention of salt accumulation, is ensured under basin irrigation by the annual connection made with the underground water table when the basin is flooded. In land perennially irrigated natural drainage may or may not be good and artificial drainage, apart in some cases from main drains, which scarcely anyone uses, does not exist. Deterioration of land under perennial irrigation can always be associated with the existence of a high water table which has persisted over a variable period of time. From a historical point of view the immediate adverse effect on crops of a high water table was clearly recognised before the war; what is presented here is an account of the changes effected by a persistently high water table on the nature of the soil itself.

Types of Water Movement

The immediate cause of a heightened water table or interference with normal underground water movements varies a great deal.* All abnormalities in water table movements, however, will take

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* For an intensive study of such water movements *see* : "Analyses of Agricultural Yield, Part IV. Water table movements on a farm in Egypt" by W. Lawrence Balls and M. A. Zagloul. Phil. Trans. Roy. Soc., Series B, 221, 335-375 (1932).

place against the background of the extremely variable nature of the surface fluviatile deposits ; even in the simplest and very common case of infiltration from a high level canal the actual course of the infiltration, and the area affected by it, have been found to be profoundly influenced by variation in the physical structure of the soil (sand and clay strata). In other cases, where land is not level, drainage to the low lying parts causes a high water table there ; in still others the practice of over-watering, in relation to the physical structure of the soil, has resulted in the repeated formation over a number of years of an artificially high water table. The essential feature in every case is that a high water table from which free evaporation can take place should persistently recur. The actual depth of the water table and the regularity of its recurrence determines respectively the nature of the infertile soil and the rapidity with which it is produced. Height above sea level has nothing whatever to do with it ; deterioration of land occurs in Upper as well as in Lower Egypt so that its determining cause depends entirely on local conditions.

Features of Basin Land

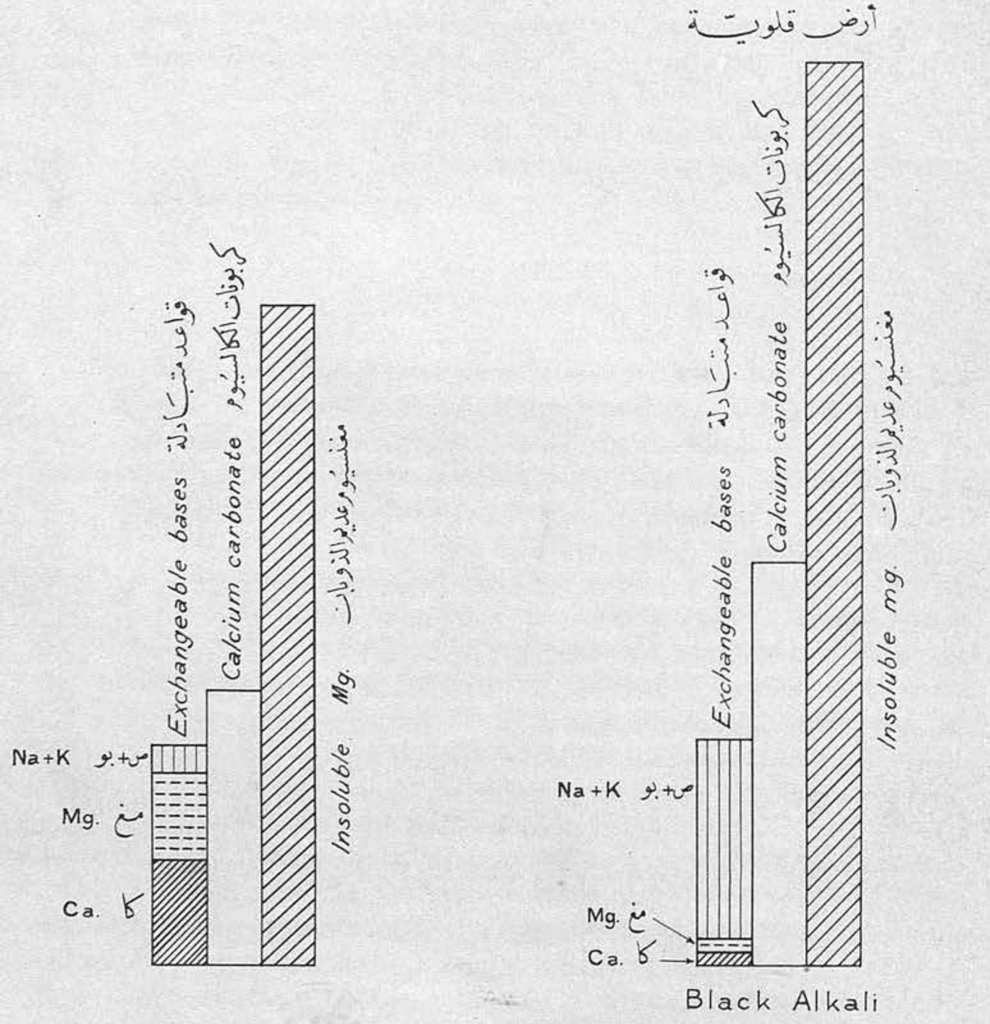
In describing the types of definite infertility produced or the deterioration of the soils of Egypt in general the standard to which all comparisons will be referred is basin land ; the latter is taken as representing not only the original condition of land now under perennial irrigation but also as (potentially) the best from the point of view of fertility. Basin land soils are highly colloidal in nature, the actual proportions of sand and clay varying to some extent with position in the basin. The proportion of the clay fraction which is present comes out at about 50 per cent and together with the silt fractions accounts for 80 per cent of the soil. This physical constitution is in turn reflected in the high saturation capacity for exchangeable bases averaging 55 milligram equivalents per 100 grammes of air dry soil. As in all fertile soils the dominant exchangeable base is calcium but exchangeable magnesium is also high and generally amounts to between a third and a half of the exchangeable calcium. The calcium and magnesium between them account for the majority of the exchangeable bases ; the exhangeable potassium, by comparison, is low while exchangeable sodium is practically absent. Calcium carbonate is always present and soluble salts, for practical purposes, are negligible. A pronounced feature of these soils is the high acid soluble magnesium—generally amounting to between 100 and 110 milligram equivalents per 100 grammes of air dry soil. Corresponding to the composition of the exchangeable

Fig Nº 1 شكل رقم ١

رسم بيانى لأظهار مميزات الأرض "القلوية السوداء" ومقارنتها بأرض اكثر خصوبة واقعة بالقرب منها

DIAGRAM TO SHOW FEATURES OF A 'BLACK ALKALI' SOIL AS COMPARED WITH A MORE FERTILE SOIL TAKEN NEAR IT

(Taken from tables II & III) (مأخوذ من الجدولين الثانى والثالث)



Sample Nº 85 عينة نمرة ٨٥ *Sample Nº 76* عينة نمرة ٧٦

مصلحة المساحة المصرية ١٩٣٤ (٣٤/٦٨٥)

bases the texture of basin land soils is good and they are freely permeable to water *.

Description of Types of Infertile Soils

In dealing with the deterioration of land under perennial irrigation, consideration (for the sake of ease in discussion) will be given first of all to the extreme and striking types of soils which may be produced; soils on which in their present condition nothing at all can be induced to grow. Such completely infertile soils generally occur in more or less isolated patches which may extend from a square metre up to many feddans in area. In some part or the whole of their profile they are in a highly dispersed condition and are, as a result of this, practically completely impermeable to water. From field and laboratory observations made on profiles taken from such spots (usually to the depth of one metre) they can be classified into two types which appeared, at first sight, to be sharply distinct, except for the common properties of impermeability to water and consequent infertility:

(1) "Black Alkali" soils.

(2) Gypsum-veined soils.

(1) Compared with the surrounding fertile soil, from which it is derived, a "black alkali" soil, in addition to its impermeability, shows the following features (*see* also fig. 1):—

(*a*) The dominant exchangeable base has become sodium instead of calcium and magnesium.

(*b*) There is a very marked increase in insoluble calcium and magnesium compounds; the calcium has been deposited mainly as carbonate and the magnesium as silicate.

(*c*) The amount of organic matter in the profile has been greatly reduced.

(*d*) The soluble salt content is low, but the "carbonate" and "bicarbonate" titration of the water extract is abnormally high.

(*e*) Analyses of the clays separated from the various horizons of such soils bring out a significantly higher silica and magnesium content as compared with normal soils.

* Tables of figures, illustrative of the types of soil discussed, are given in the appendix.

(*f*) In the field they are extremely retentive of water and difficult to dry out.

(*g*) In the field a black skin of organic matter is sometimes present at the surface—hence the name " black alkali " or " Armout ".

The adverse physical properties of such soils, their highly dispersed condition and impermeability to water, are to be directly connected not only with the fact that the dominant exchangeable base is sodium but also with the presence of the precipitated magnesium silicate.

(2) *The gypsum-veined soils* appeared, at first, to have in common with the " black alkali " only their infertility and impermeability to water. From laboratory examination (and again compared with the fertile soils immediately surrounding them) the organic matter and calcium carbonate distribution in the profile remain entirely normal while any increase in insoluble magnesium may be relatively slight. Soluble calcium, magnesium and sodium salts, in varying proportions and amounts, are always present. It is naturally difficult to make any very definite statement about the composition of the exchangeable bases but they would appear to be accounted for mainly by calcium and magnesium, the proportion of the latter being frequently abnormally high. A constant feature of the profile in the field is the presence at a variable depth of an impermeable layer. This layer may be constituted by the surface soil itself or may be situated 40 centimetres or more below it ; whatever its situation it is generally, but not invariably, immediately underlain by a horizon veined with gypsum and of good texture. Whether or not the veined horizon is present the gypsum itself (accompanied by salts of sodium and magnesium) is always there. The soluble salts, including gypsum, occur in all layers of such a profile but there is typically a peak concentration in the veined horizon immediately beneath the impermeable layer (*see* fig. 2). These gypsum-veined soils in the field show markedly greater retentive powers for moisture than fertile soils and when their profiles are examined in a moist condition the impermeable layer stands out as being in such a highly dispersed condition that the fine capillaries are obliterated and very little water movement through it can be possible. On drying out, such impermeable layers become extremely hard and difficult to break. It will readily be understood that these soils present a difficult problem and it was at first very difficult to understand why colloidal systems containing such amounts of soluble salts should be impermeable to water at all. On suspension in distilled water they flocculate at once leaving a clear supernatant liquid. Analyses of clays separated from impermeable layers have shown that their

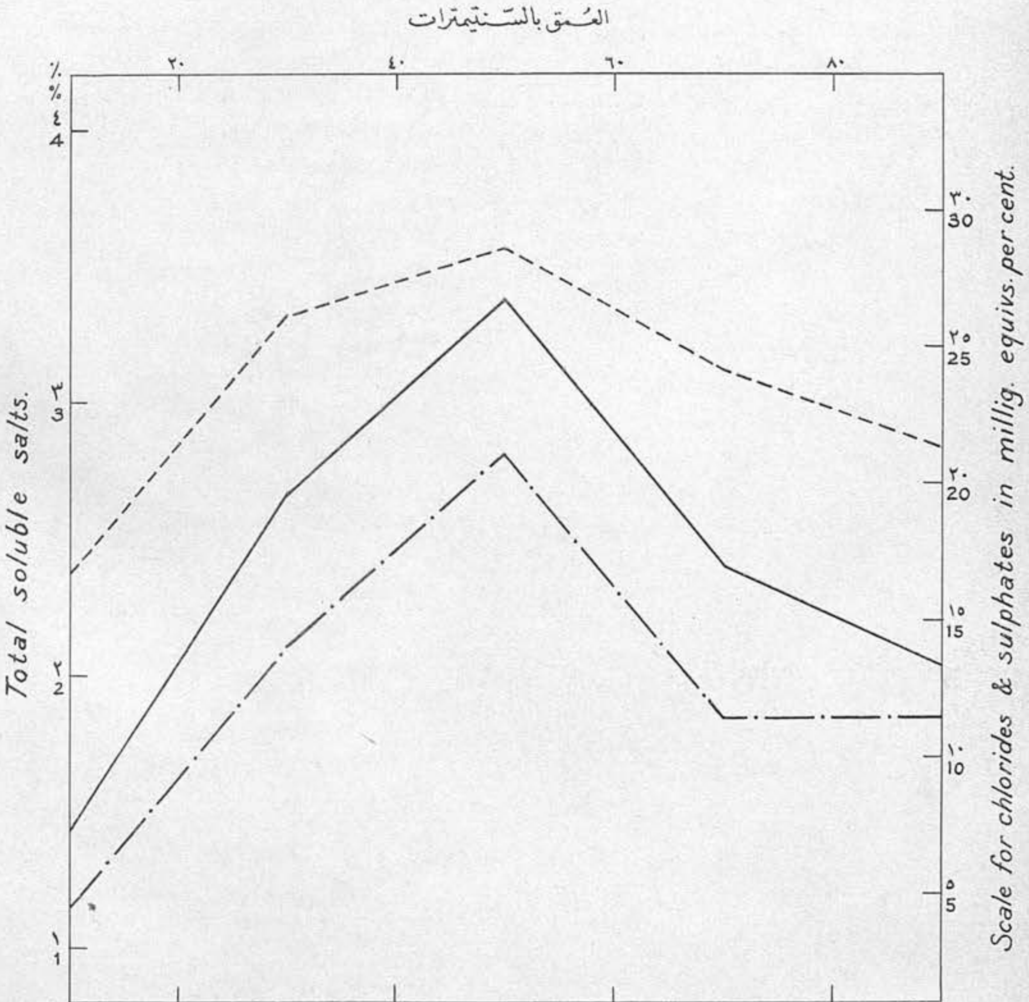
Fig. № 2

شكل رقم ٢

توزيع الأملاح في القطاع (هـ) ذى العروق الجبسية

DISTRIBUTION OF SALTS IN THE GYPSUM-VEINED PROFILE (E)

(Of table I) (مأخوذ من الجدول الأول)



Chloride - - - - - - - كلورور *Sulphate* . ___ . ___ . كبريتات

Total soluble salts _______ مجموع الاملاح الذائبة

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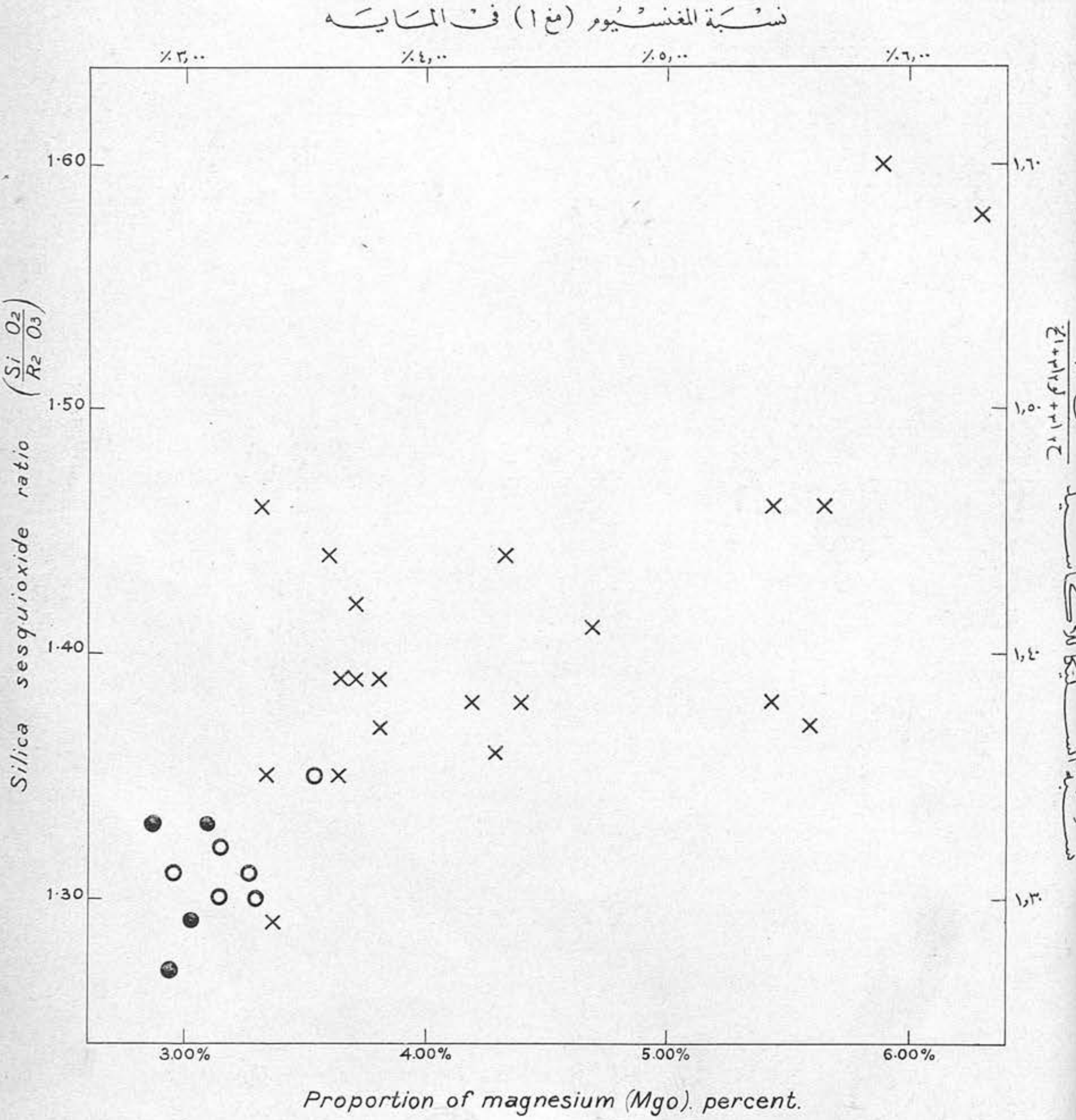
Fig-N° 3 شكل رقم ٣

العلاقة بين النسبة $\frac{\text{سليكا}}{\text{اكاسيد سداسيه}}$ والمغنسيوم الذى يحتويه الطين

RELATIONSHIP BETWEEN THE SILICA SESQUIOXIDE RATIO AND THE MAGNESIUM CONTENT OF CLAYS



Basin land. ● أرض حياض

Fertile perenially irrigated land. O أرض خصبة خاضعة للرى الصيفى

Clays separated from more or less abnormal soils. X طين مفصول من أرض ضعيفة قليلا أو كثيراً

ـلعة المصرية سنة ١٩٣٤ (٣٦/٦٨٥)

physical properties can be correlated with an abnormally high proportion of silica; the soil will still flocculate in water but the physical properties of the solid phase have been altered by the deposition of silica. The form in which this silica is present has not yet in all cases been determined; in a few it appears, as with the " black alkali " soils, to exist in the form of magnesium silicate (*see* fig. 3).

Interrelation of Types of Infertility

When observations (such as are described above) were extended to a wider range of material the position as regards these two types of infertility, apparently so distinct, became much clearer and it soon appeared that they were in fact closely connected. Profiles have been studied in which the whole sequence of surface soil, impermeable layer and gypsum veins is underlain by a sodium clay, *i.e.* by typical " black alkali " as described above; the reverse order is never the case. Moreover, the examination of infiltrated land in the field has shown a direct connection between *type* of infertility and *height* of the water table. Close to a high level canal where the water table is naturally highest the " black alkali " type is produced, while towards the outer edge of this same infiltrated area the gypsum-veined type is found. Again, in an area of land which had been more or less waterlogged for some years the gypsum-veined type was found on the highest part (lower water table) while soil more or less of the " black alkali " type was found on the low lying parts.

The final result of subjecting a soil to poor drainage conditions over a number of years depends therefore on the average height attained by the water table. If it is very high a " black alkali " soil will result; as it becomes lower this soil type will be replaced by various stages of the gypsum-veined type underlain by " black alkali "; and if the water table remains low enough the soil will remain normal and as fertile as before. The exact moment in time when an infertile spot will emerge depends on how drastic the unfavourable conditions are, *i.e.* on the height, duration and regularity of each raising of the water table and the frequency with which it recurs. Taking the country as a whole, in the absence of remedial measures, the areas of existing infertile soils must be expected to increase, while fresh infertile spots must continually be making their appearance, as actually they do.

Classification of These Infertile Soils

Before going on to outline the nature of the biochemical processes involved in the production of these infertile soils in Egypt it will be useful to consider them in relation to the description of such soils from other countries and the theories adopted to account for their origin.

According to the Russian scheme (Vilensky) of classification of alkali soils, the type here described as " black alkali " would correspond to a " solonetz " and the gypsum-veined type to "regraded solonetz ". That is to say that Vilensky regards the regraded solonetz as having arisen from a pre-existing solonetz by a subsequent rise of ground water containing salts. The solonetz itself is characterised by having sodium as the dominant exchangeable base, by the presence of sodium carbonate arising from hydrolysis of the sodium clay, by the absence or low content of other soluble salts, by its impermeability to water and by the possession of a characteristic structure. With the exception of the structure all of these are features held in common with the " black alkali " soils of Egypt. A solonetz is said to arise as the result of a direct base exchange between accumulated sodium salts and the exchangeable calcium of the soil, the resulting calcium chloride or sulphate being washed out. Von Sigmond in Hungary has emphasised that (as in Egypt) the primary condition for the production of an alkali soil in that country is an interference with good drainage, but has otherwise put forward the same theory to account for their origin and for the pressence of sodium carbonate. Kelley in American has published similar views on the alkali soils of the United States.

The gypsum-veined soils of Egypt are not analogous to the " regraded " solonetz. Both from field observations and from the analyses made on them they must be regarded as a primary formation arising concurrently and in association with the " black alkali " soils by a direct alteration of the original soil; they cannot have arisen secondarily through the " regrading " of pre-existing " black alkali " soils since they are sharply distinguished from the latter in that their calcium carbonate and organic matter profiles remain entirely normal while the increase in insoluble magnesium may be relatively slight. In the mixed profiles, where the gypsum-veined horizon is underlain by a sodium clay, the amount of calcium carbonate present never becomes abnormal until that sodium clay is reached (the region of deposition of the insoluble magnesium may be higher up in the profile). Finally in this connection it will be recalled that the gypsum-veined soils are associated in the course of their formation with an initially lower level of the water table than the " black alkali " soils.

The " black alkali " soils themselves, while agreeing with the solonetz type in the features already enumerated have in addition as equally salient features their large increases in calcium carbonate and magnesium silicate and their decrease in organic matter as compared with normal soils.

Processes involved in the Formation of Infertile Soils

Any account of the processes involved in the formation of " black alkali " soils must explain these increases in insoluble calcium and magnesium compounds equally with the fact that the dominant exchangeable base has become sodium. The important thing in this explanation is not necessarily to provide conditions for the accumulation of sodium salts but rather to provide conditions in which the solubility of calcium and magnesium salts will be diminished. The following explanation of the reactions involved takes its origin in the experimental glass-fronted pits originally constructed by Dr. J. Templeton, Director of the Botanical Section, for the observation of water table effects on plant roots. When the water table is raised a blue colour, due to ferrous sulphide, always develops markedly round the living roots and subsequently in the whole body of the soil which is waterlogged. Such a blue colour in fact is always developed on waterlogging any soil in Egypt containing organic matter. The sulphate reduction (sulphate is always present in Nile water) is carried out by a *Microspira*, a variety of *Microspira desulphuricans* (Beijerinck), which utilises the oxygen so obtained for the oxidation of organic matter. A strain of this organism has been isolated in the laboratory and preliminary observations on culture solutions have shown that its activities may result in a marked increase in the alkalinity of the medium in which it is grown. There seems to be every justification for advancing an hypothesis that the production of " black alkali " soils in Egypt in conditions of poor drainage takes place in a medium already rendered alkaline through the activities of this organism. The increased alkalinity depresses the solubility of the calcium and magnesium salts present and so permits of a base exchange between the sodium salts remaining in solution and the exchangeable calcium and magnesium of the soil. Nile water itself must be regarded as a suitable irrigation water ; except during the period of low stage in June and July the calcium is always in excess of the sodium and even during that period the water must still be regarded as being, on the whole, good for irrigation purposes since the sodium is never greatly in excess of the calcium.* From a theoretical point of view, considering that calcium is absorbed preferentially to sodium by the soil, there is no reason why the mere waterlogging of a soil with such a water

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* This statement is based on unpublished work done in the Chemical Section on Nile and Canal waters by R. Aladjem.

should result in the replacement of the exchangeable calcium of the soil by sodium. That replacement cannot occur until the proportion of calcium present in solution becomes very small relatively to the sodium. Increase in alkalinity through the activity of the *Microspira* provides the conditions necessary for the modification of the water. During the summer of 1933, using Nile water alone, experimental waterlogging of two of the glass-fronted pits already mentioned duly resulted in the partial conversion of the soil in them to sodium clays. The waterlogging caused, as always, a marked development of the blue colour in the pits. The composition of the water concerned in the waterlogging will not necessarily, however, be that of Nile water. The results of a comprehensive survey of the composition of the underground waters of the Botanical Section farm at Giza carried out during two complete years by Dr. Williamson show that the composition of such waters can be modified quite quickly and through very short subterranean passages in a systematic and dangerous manner.

In this manner, concurrently with the replacement of the exchangeable calcium and magnesium of the soil by sodium, there will ensue a deposition of calcium carbonate and magnesium silicate. And if the water table has been at or near the surface and the process has gone so far that the dominant exchangeable base has become sodium the infertile soil so produced will then have all the properties of " black alkali " already described.

Where a gypsum-veined soil occurs at the surface one can infer that the sodium clay had originally been formed lower down, corresponding to the initially lower level of the water table associated with soils of this type. With continued irrigation etc., the level of waterlogging will become progressively higher. Salts and possible decomposition products from the sodium clay will accumulate through evaporation which will eventually take place from the surface of the soil itself. The final stages may be quite rapid and the soil apparently become infertile quite suddenly. It must be confessed that while an accurate description can be given of the nature and properties of these gypsum-veined soils and the broad outline of the course of their formation seems clear, yet the more intimate details of such formation are still necessarily obscure.

Deterioration of Land in General

Between these two extreme and striking types of infertility on the one hand and first class land on the other there exists a whole range of more or less serious departures from the normal. This is to be expected from the variety of water movements possible, and it has already been pointed out that, in the absence of remedial

COTTON EXPERIMENTS

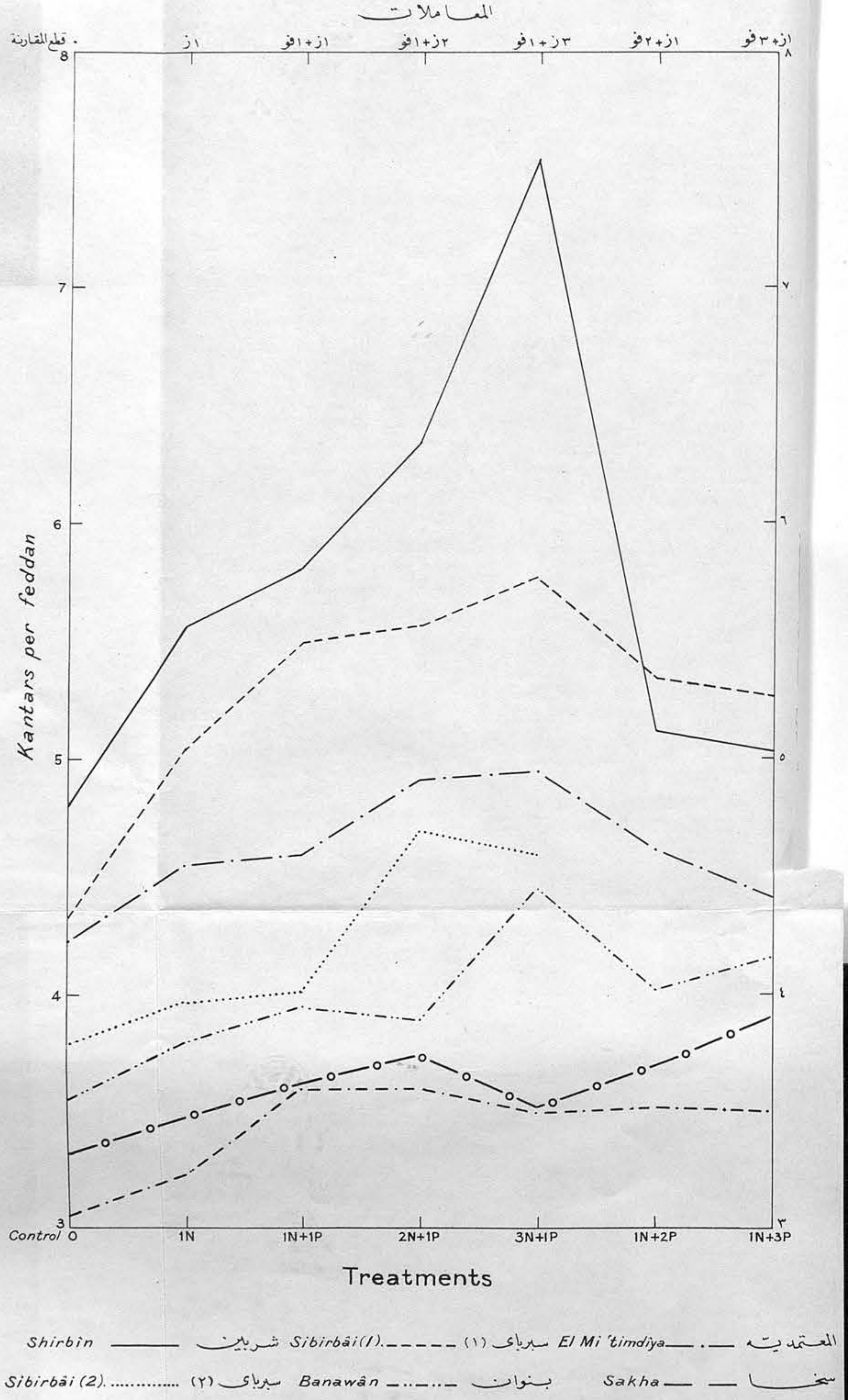
تجارب القطن

تجارب على تسميد القطن السكلاريدس اجريت عام ١٩٣٢ وضع محصول الفدان فى محور والمعاملات فى المحور الآخر

MANURIAL EXPERIMENTS WITH THE VARIETY SAKEL 1932
YIELDS PER FEDDAN PLOTTED AGAINST TREATMENTS

Note.—*1N = 100 kilos Nitrate per feddan.*
1P = 100 kilos Superphosphate per feddan.

ملاحظة - ١ ز = ١٠٠ كيلوجرام نترات للفدان
١ فو= ١٠٠ كيلوجرام سوبر فسفات للفدان



COTTON EXPERIMENTS

تجـــارب القطـــن

من تجارب على تسميد القطن الاشموني الجديد اجريت عـام ١٩٣٣ وضع محصول الفدان في محور والمعاملات في المحور الآخر

MANURIAL EXPERIMENTS WITH THE VARIETY ASHMOUNI GEDID 1933

YIELDS PER FEDDAN PLOTTED AGAINST TREATMENTS.

Note.— *1N= 100 kilos Nitrate per feddan.*

1P=100 kilos Superphosphate per feddan.

ملاحظة ـ ١ ز = ١٠٠ كيلوجـرام نترات للفـدان

١ فو = ١٠٠ كيلوجـرام سوبرفوسفات للفـدان

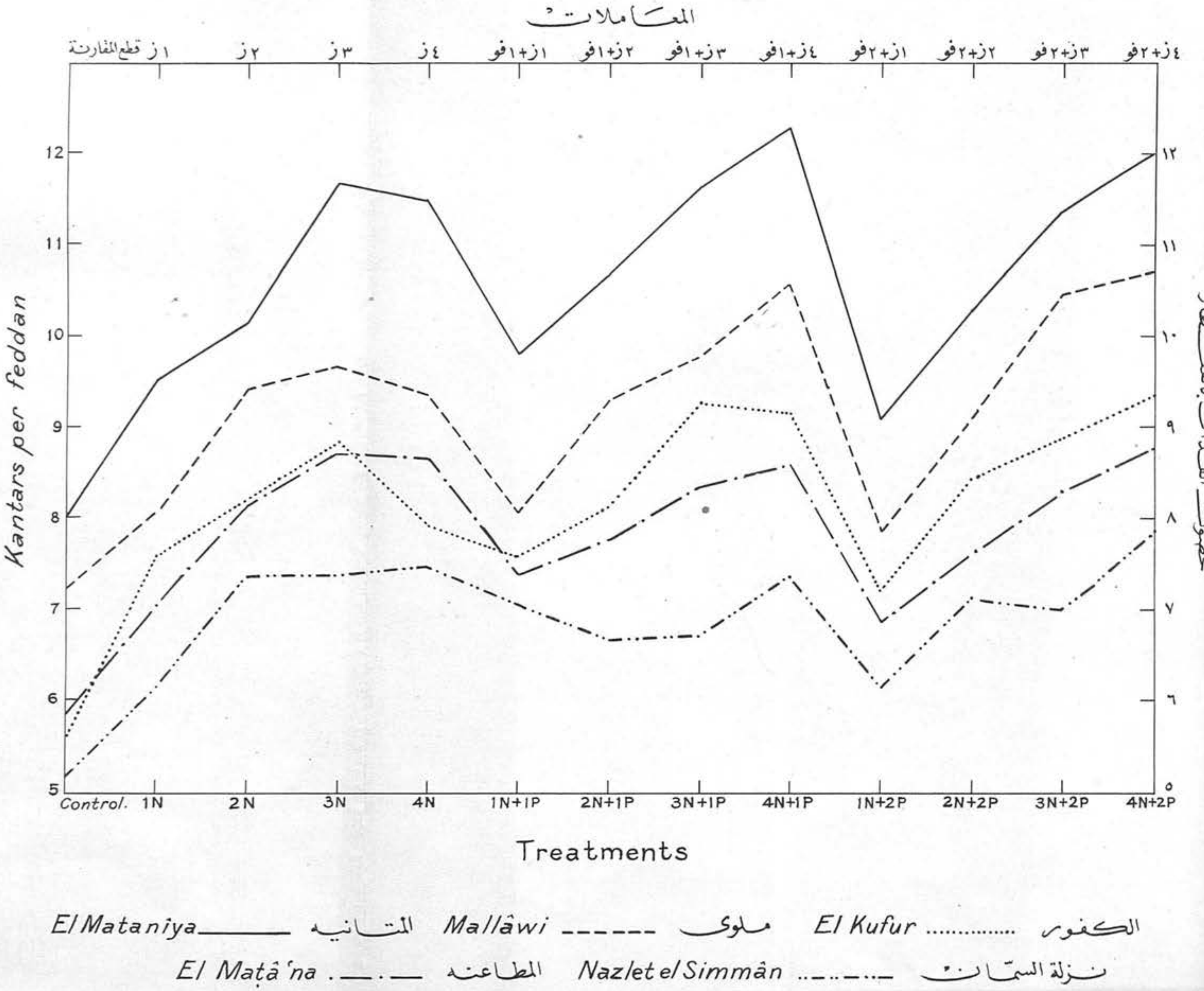


Fig. N: 4

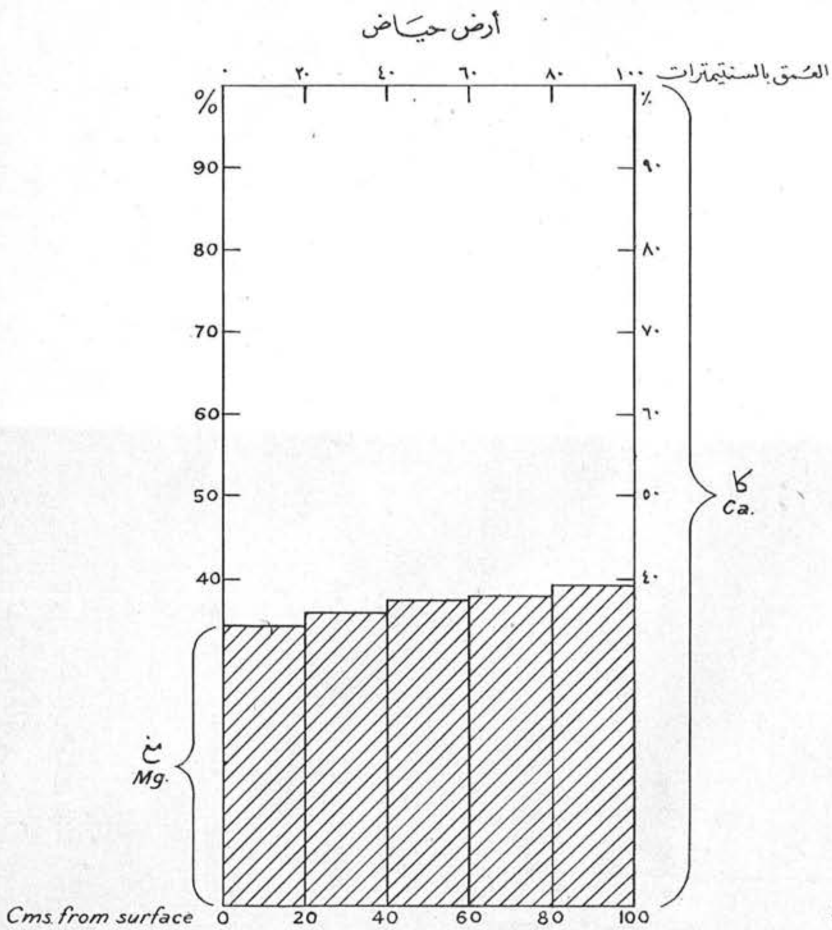
شكل رقم ٤

نسبة المغنسيوم المتبادل الى الكلسيوم المتبادل فى أراض حوضية وأراض تروى ريا صيفيا

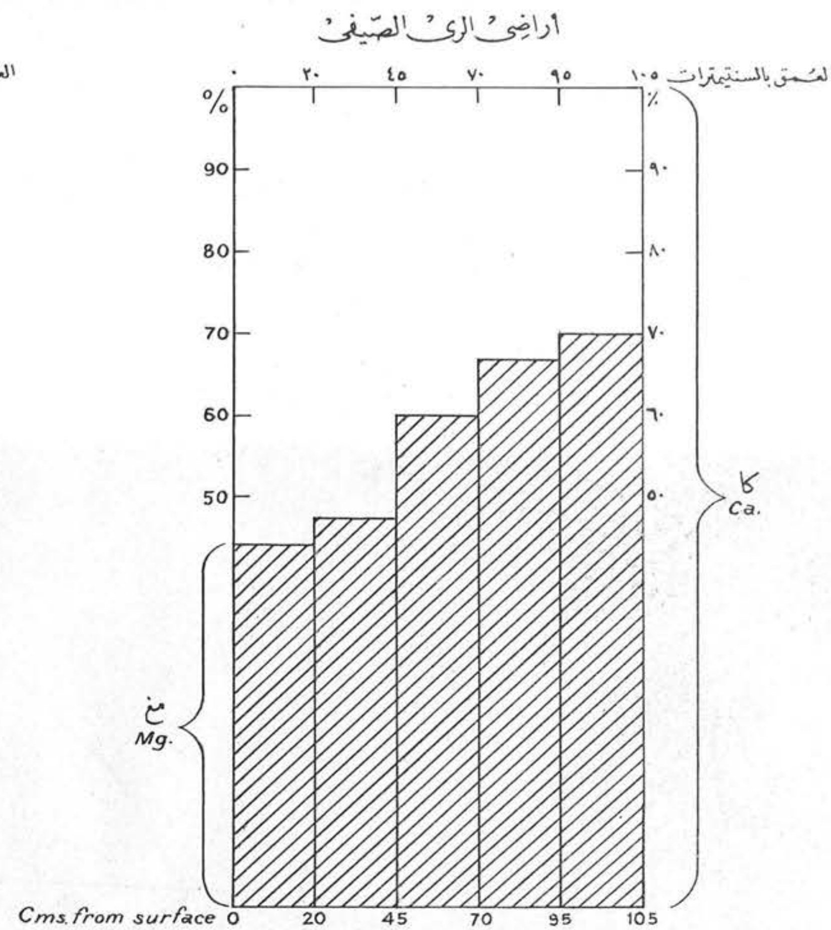
PROPORTIONS OF EXCHANGEABLE MAGNESIUM TO CALCIUM IN BASIN LAND AND FERTILE PERENNIALLY IRRIGATED LAND

(*Taken from table II*)

(مأخوذة من الجدول الثانى)



Basin land



Perennially irrigated land

measures, existing infertile areas must tend to increase their extent while fresh areas must continually be making their appearance. The commonest departure from the normal in soils still classed as very fertile is an increase in the proportion of exchangeable magnesium. In basin land a slight tendency for the ratio of exchangeable magnesium to calcium to increase with the depth has already been noted: in perennially irrigated land this practically always happens and in addition (even in the surface layer) the ratio is much higher (*see* fig. 4). The precise meaning or cause of this increased proportion of exchangeable magnesium is not quite clear. Magnesium like sodium confers adverse physical properties on the soil when it is the dominant exchangeable base, so that an increase in its proportion is probably indicative of deterioration in a soil.

Effects of Soil Deterioration on Crop Yields

The significance of the whole situation as regards crop growth may perhaps best be illustrated by a consideration of the nature of the results obtained in an extended series of manurial trials with cotton and maize [1]. In figs. 5 and 6 average yields of cotton per feddan are plotted against the manurial treatment with which they were obtained. It is at once evident from the parallelism of the curves in fig. 5 that the maximum yield of cotton attainable on any piece of land is primarily determined by factors other than the fertilisers employed and only secondarily by the latter [2]. This statement is not to be taken to mean that fertilisers have no effect on cotton but merely that these other factors determine the maximum amount of production actually possible in any given case. Fig. 6 is drawn from results obtained with the variety Sakel during experiments conducted in 1932. This variety is mostly grown in the Northern half of the Delta in parts of which the water table naturally tends to be, or have been, higher than is the general rule elsewhere. In addition to the general parallelisms shown by fig. 5 the trend of the curves suggests that even the proportion of increase obtainable from manuring may be determined by the other factors. *In other words cotton grown on low yielding land may respond less to manuring than cotton grown on high yielding land.* (In passing it may be remarked that this has often been incorrectly expressed by saying that Sakel is a variety

1. These experiments were carried out by the Agronomic Section and we are indebted to Hussein Eff. Enan for the results.

2. *See* also in this connection a report by Frank Hughes on manurial trials on cotton in the Year-book of the Khedivial Agricultural Society for 1909.

which does not respond to manuring.) In fig. 7 the maximum percentage increases obtained from manuring in a series of field experiments with Ashmouni Gedid for the years 1931–1932–1933 are plotted against the appropriate control plot yields. The irregular nature of the result is to be compared with the regularity of a similar diagram plotted from the results of experiments with the maize variety American Early carried out in the years 1932 and 1933 (*see* fig. 8). The diagram from the maize experiments brings out clearly the fact that the greatest response is obtained on low yielding land and the least on high yielding *i.e.* that for the country as a whole there is one maximum yield for maize towards which the crop may be pushed on any soil by suitable manuring. With cotton on the other hand manuring can only raise or depress the yield around a previously determined level. This difference in reaction to fertilisers must be considered to be due mainly to the fact that the deeper rooting cotton plant is more affected by subsoil conditions than the shallower rooting maize. The level of yield of cotton attained on any land will therefore effectively correspond to the amount of deterioration the land has undergone.

Necessity for Drainage

The remedy for the state of affairs described is the entire prevention of the deterioration of land by the installation of a system of intensive drainage combined with defenses against infiltration. This means not only main drains but also field drains*.

It will be borne in mind, of course, that the present communication is a preliminary account of a survey of the nature of land deterioration in Egypt. A more accurate idea of the rate of deterioration and the amount of land involved can only be obtained from quantitative surveys directed to find out the past and present conditions of large areas of land under perennial irrigation, arriving in this way at some conclusion as to the urgency of the situation. Even with intensive field drainage, however, it is possible that infiltration from high level canals may have to be arrested by lining the canals.

Prospects of Amelioration of Deteriorated Land

This question of the installation of intensive drainage is a very pressing one from another point of view, in that the reclamation of the *extreme types* of infertility produced presents a very difficult problem.

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* From an economic point of view intensive drainage comes down to pipe drainage of the individual feddan.

Fig. № 7

شكل رقم ٧

COTTON EXPERIMENTS

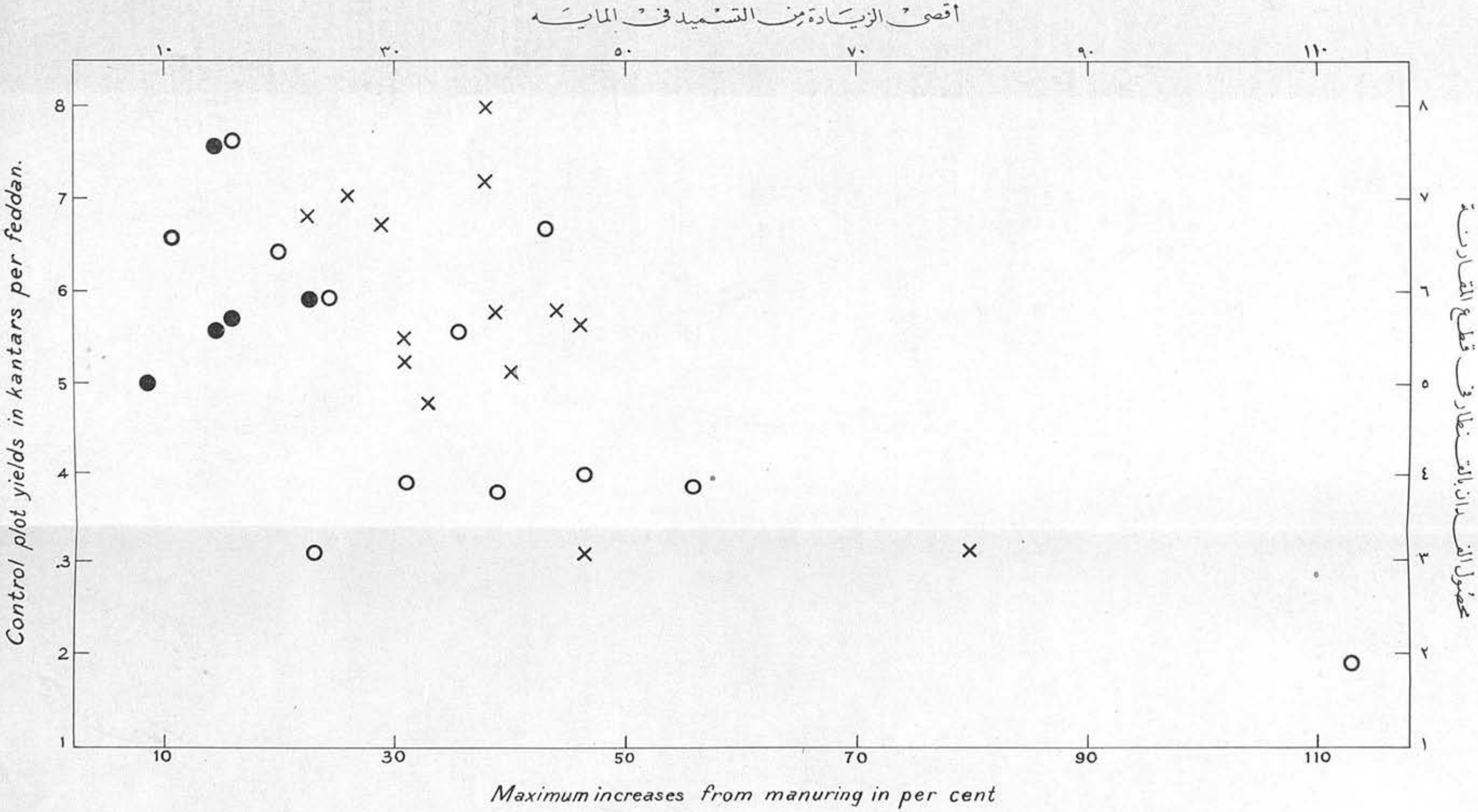
تجارب القطن

وضعت النسبة المئوية لزيادة المحصول من التسميد في محور ومحصول قطع المقارنة في المحور الآخر

PERCENTAGE INCREASES FROM MANURING PLOTTED AGAINST CONTROL PLOT YIELDS

Variety : *Ashmouni.*

الصنف : أشموني



1931 ● ١٩٣١ 1932 ○ ١٩٣٢ 1933 × ١٩٣٣

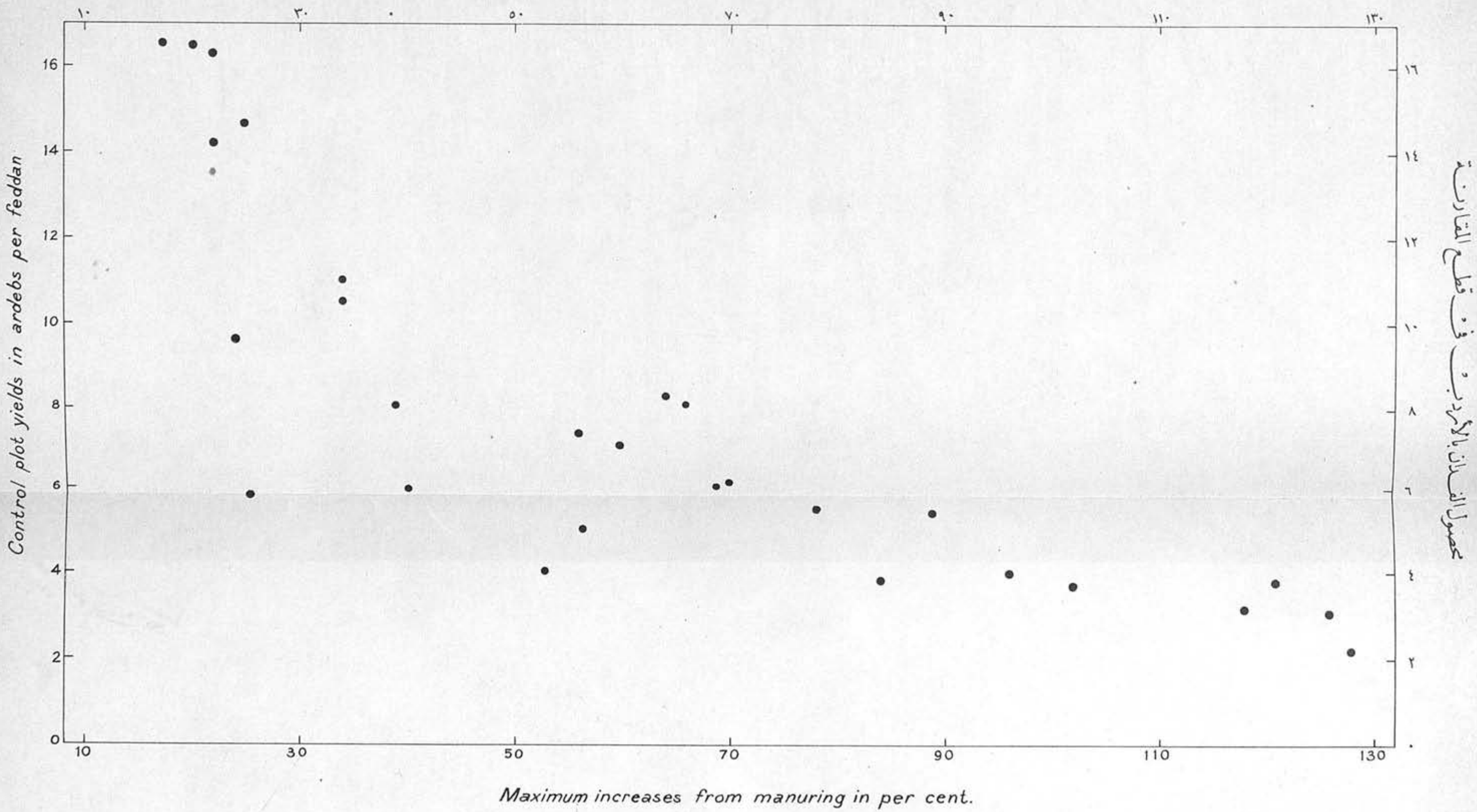
مصلحة المساحة المصرية ١٩٣٤ (٦٨٥/٣٤)

MAIZE EXPERIMENTS (1932 & 1933) (١٩٣٣ ، ١٩٣٢) تجارب الذره

النسبة المئوية لزيادة المحصول من التسميد موضوعة فى محور ومحصول قطع المقارنة فى المحور الآخر

PERCENTAGE INCREASES FROM MANURING PLOTTED AGAINST CONTROL PLOT YIELDS

Variety: *American Early.* الصنف - أمريكانى بدرى



مصلحة المساحة المصرية ١٩٣٤ (٣٤/٦٨٥)

(The term "reclamation" in Egypt is generally taken to mean the levelling, draining and washing of waste salty lands in the North of the Delta. Such reclamation is to be sharply distinguished from that under discussion here. The soils of these waste areas are not necessarily of the type produced in the deterioration of fertile land and the problem they present is mainly one of salt; once that is washed out they are generally fertile.)

The general experience with "black alkali" soils in other countries is that if they are drained concurrently with an application of gypsum conditions are achieved which provide for the replacement of the exchangeable sodium by calcium and the soil "reclaims"; *i.e.* calcium again becomes the dominant exchangeable base and the soil recovers its texture and permeability. With the extreme types of "black alkali" soils in Egypt, however, the situation is complicated by the fact that the magnesium silicate precipitated in them during their formation contributes to their impermeability. Even were this not the case their highly colloidal nature would make them extremely difficult to deal with. It should also be clearly recognised that the worst conditions do not occur at the surface but that typically in such profiles both the proportion of exchangeable sodium and the amount of insoluble magnesium increase with depth. In the meantime although recommendations about the applications of gypsum in conjunction with drainage have frequently been made for such soils in the past, there is no real evidence as to the exact extent to which the application of soluble calcium salts is useful. In one experiment carried out over a number of years on an area of the extreme type of "black alkali" soil the drains installed have caused a slight improvement on the edges of the plots but it cannot be said that the successive applications of gypsum to the treated plots have had more than a very slight effect. This is in addition to the fact that as Nile water is a suitable irrigation water the soluble calcium in it should also be exercising its effect. Moreover, a high proportion of the calcium carbonate present in Egyptian soils is in a very fine state of division and can be separated out with the clay, a further feature which should aid in reclamation. Profiles belonging to the same extreme type have also been secured from areas on which neither gypsum nor drainage have had any effect. In cases where the changes impressed on the originally fertile soil have not been of such a drastic nature it is quite possible that an application of gypsum in conjunction with drainage might hasten the process of reclamation. As stated above, however, efficient drainage is the all-important element in the reclamation and no general attempt has been made to separate the respective effects of drainage and gypsum.

The original difficulty with the gypsum-veined soils was to find the reason why colloidal systems containing such large amounts of soluble salts should be impermeable to water at all. This feature has been shown to be associated with a layer lying above the gypsum horizon, and clays separated from such layers have been found to have a higher silica-sesquioxide ratio than clay from normal soils. Consideration of their amelioration again brings drainage into the foreground. It is said that if they are drained they slowly improve, but again as with the question of the usefulness of gypsum on the "black alkali" type there are no systematic observations on which to base an opinion. The application of gypsum is obviously needless—on the contrary the larger the amounts of gypsum and soluble salts present the worse conditions appear to be. Profile No. 7 of the tables, for example, contains in its surface layers gypsum equivalent to 100 tons per feddan and although the area from which the profile was taken had been drained for three years at the time of sampling no improvement had taken place. The only other obvious possibility for hastening the reclamation would be trenching or deep-ploughing to break through the impermeable layer. Again as with the "black alkali" type all imaginable stages exist between the completely infertile stage and the unaltered soil.

In conclusion it can be said that, throughout the country, soil deterioration is undoubtedly coming to be associated in the public mind more and more with poor drainage conditions. The installation of an intensive drainage system should, however, be regarded as a purely preventive measure. It is advocated mainly from the point of view of the conservation of the fertility of fertile land and only secondarily from the point of view of the reformation of deteriorated land. A serious warning must be given that, even with good drainage, the amelioration of land already deteriorated may be disappointingly slow.

APPENDIX

In illustration of the foregoing preliminary report on soil deterioration in Egypt analytical figures are given in the following tables for seven profiles, selected to be representative of the various types discussed. The report itself, however, is actually based on a similar systematic examination of some seventy profiles from all over the country. The seven profiles include:

(*a*) Basin land.

(*b*) Fertile perennially irrigated land.

(*c*) " Black alkali " soil.

(*d*) A profile from more fertile land taken a few metres from (*c*).

(*e*) A gypsum-veined soil.

(*f*) A more fertile soil taken a few metres from (*e*).

(*g*) A mixed profile *i.e.* a gypsum-bearing soil underlain by a sodium clay.

Profiles (*d*) and (*f*) have been introduced solely for the sake of comparison respectively with the " black alkali " soil (*c*) and the gypsum-veined soil (*e*). While the two former profiles are used for comparative purposes in this manner they must not themselves be regarded as normal soils. Thus profile (*d*) taken near the " black alkali " profile has obviously been influenced to some extent by the conditions which have produced the latter: considerable exchangeable sodium is already present (table II) and the insoluble magnesium is somewhat high (*see* table III and clay sample No. 85 of table IV). Again profile (*f*) taken near the gypsum-veined soil (*e*) also shows gypsum veins in the layer between 40–60 centimetres although not to the same marked extent as profile (*e*).

As regards the analytical figures themselves the difficulty, with soils containing soluble salts and gypsum, of giving an accurate figure for exchangeable calcium and magnesium has already been pointed out. Even in the absence of soluble salts the exact determination of these bases must be affected by the presence of calcium and magnesium carbonates and silicates. Experiments undertaken on the point have shown that the insoluble carbonate in Egyptian soils is mostly if not wholly present in the form of calcium carbonate and that magnesium can account for at most ten per cent. In table III therefore the carbonate has all been expressed as calcium carbonate and the magnesium assumed to be present wholly in some form of silicate. The exchangeable bases were determined by leaching with normal sodium chloride solution. The quantity of soil taken for each determination was adjusted so that all of the exchangeable calcium and magnesium came out in the first extraction. The amounts of calcium and magnesium then obtained from the second and third extraction of the same quantity of soil were approximately constant, the amount of magnesium being low (of the order of 1·5 milligram equivalents per cent for fertile soils) while the amount of calcium is important. In calculating the exchangeable base figures allowance has always been made for the solubility effect of the sodium chloride on calcium carbonate while the magnesium obtained from the first extraction has been taken as being the exchangeable.

The saturation capacity* was determined by leaching the soil with calcium chloride solution to replace all the exchangeable bases, washing free from chloride and then leaching with normal sodium chloride solution. In calculating results allowance was again made for the solubility effect of sodium chloride on calcium carbonate.

Acknowledgement is made to Dr. Fahmy Khalil and M. Kadi Eff., for the organic matter and total nitrogen estimations and to Mohammed Ahmed Ali Eff., for the determinations of insoluble carbonate.

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* *See* I. I. Kaniwetz, Proc. I. S. S. S., 1931, No. 3, p. 107.

Table I.—Water Soluble Constituents

Figures are given in milligram equivalents per cent of the air dried soil.

Sample No.	Depth of Layer in cms.	Ca	Mg	CO_3	HCO_3	Cl	SO_4
(a) *Basin Land.*							
314	0–20	1.0	traces.	0	2.2	0.3	0.4
315	20–40	1.0	,,	0	2.1	0.3	0.5
316	40–60	1.0	,,	0	2.2	0.3	0.6
317	60–80	0.8	,,	0	2.0	0.4	0.6
318	80–100	0.8	,,	0	2.2	0.4	0.5
(b) *Fertile perennially irrigated land.*							
391A	0–20	1.5	0.4	0	3.3	0.2	trace.
391B	20–45	0.9	0.2	0	2.9	0.1	,,
391C	45–70	0.6	trace.	0.1	3.1	0.2	,,
391D	70–95	0.3	,,	0.2	3.4	0.3	,,
391E	95–105	0.1	,,	0.1	3.7	0.5	,,
(c) " *Black Alkali.*"							
74	0–15	0	0	**1.4**	**6.7**	0	1.8
75	15–30	0	0	**3.7**	**4.8**	0	1.1
76	30–55	0	0	**2.5**	**6.0**	0	0.8
77	55–80	0	0	**0**	**10.4**	0	0.5
78	80–105	0	0	**0**	**8.3**	0	0.5
(d) *More fertile land taken a few metres from the " Black Alkali " of* (c) *and to be used for comparison with it.*							
83	0–20	0.8	trace.	0	3.1	0.6	0.3
84	20–25	0.5	,,	0	2.9	0.5	0.4
85	25–55	0.5	,,	0	2.7	0.6	0.3
86	55–85	0.4	,,	0	2.3	0.3	0.3
87	85–110	0.5	,,	0	2.4	0.5	0.3
(e) *Gypsum-veined soil.* *The impermeable layer is between* 20 *and* 40 *cms., the gypsum-veined horizon between* 40–60 *cms.*							
112	0–20	**1.7**	1.8	0	1.6	16.9	4.6
113	20–40	**6.7**	4.3	0	1.1	26.6	14.0
114	40–60	**10.5**	6.3	0	1.6	28.7	21.1
115	60–80	**4.6**	2.9	0	1.3	24.4	11.5
116	80–100	**4.3**	2.9	0	1.5	21.7	11.5

TABLE 1.—WATER SOLUBLE CONSTITUENTS (*contd.*)

Sample No.	Depth of Layer in cms.	Ca	Mg	CO_3	HCO_3	Cl	SO_4
	(f) *More fertile soil taken a few metres from* (e).						
117	0–20	0.3	traces	0	3.0	0.9	0.6
118	20–40	0.2	,,	0	3.5	1.4	10.6
119	40–60	5.7	2.1	0	2.3	1.6	17.5
120	60–80	4.6	2.0	0	1.9	2.4	22.9
121	80–100	4.6	2.1	0	2.8	3.5	22.9
	(g) *Profile of a gypsum-bearing soil underlain by a sodium clay (layer 392c)*						
392 A	0–15	**54.7**	20.5	0	1.1	32.7	76.4
392 B	15–30	**99.0**	23.3	0	1.2	23.6	122.8
392 C	30–50	0.1	0.8	**0.9**	**5.0**	19.2	4.4

ERRATUM

The figures for milligram equivalents per cent of water soluble magnesium for samples numbered 392 A, B and C should be 10·3, 11·7 and 0·4 respectively.

TABLE II.—SODIUM CHLORIDE EXTRACTIONS, *i.e.* ESTIMATIONS OF EXCHANGEABLE CALCIUM AND MAGNESIUM AND OF THE SATURATION CAPACITY

Figures are in milligram equivalents per cent of the air dried soil.

Sample No.	Depth of Layer in cms.	Exchangeable			Saturation Capacity	Percentage of Saturation Capacity occupied by Sodium and Potassium
		Ca	Mg	Ca + Mg		
			(a) *Basin Land.*			
314	0–20	42.4	14.4	56.8	58.0	—
315	20–40	42.3	15.0	57.3	57.9	—
316	40–60	42.2	15.7	57.9	—	—
317	60–80	42.3	15.8	58.1	—	—
318	80–100	41.4	16.2	57.6	—	—
			(b) *Fertile perennially irrigated land.*			
391 A	0–20	27.8	12.4	40.2	41.4	—
391 B	20–45	28.9	13.7	42.6	42.9	—
391 C	45–70	27.4	16.5	43.9	—	—
391 D	79–95	25.7	17.2	42.9	—	—
391 E	95–105	25.9	18.2	44.1	—	—
			(c) "*Black Alkali.*"			
74	0–15	5.7	4.3	10.0	37.2	**73.1**
75	15–30	2.7	2.1	4.8	42.4	**88.7**
76	30–55	2.0	2.5	4.5	41.6	**89.2**
77	55–80	2.9	3.6	6.5	—	—
78	80–105	5.1	6.7	11.8	—	—
			(d) *More fertile land taken near* (c).			
83	0–20	20.6	14.6	35.2	39.0	9.7
84	20–25	19.8	15.4	35.2	—	
85	25–55	19.4	15.1	34.5	38.8	11.1
86	55–85	18.5	15.7	34.2	37.9	9.8
87	85–110	17.2	18.0	35.2	—	
			(e) *Gypsum-veined soil.**			
112	0–20	(21.1)	(19.7)	—	42.5	
113	20–40	(26.7)	(20.7)	—	42.5	
114	40–60	(33.0)	(20.6)	—	43.4	
115	60–80	(24.2)	(19.1)	—	41.9	
116	80–100	(23.1)	(18.9)	—	43.0	

* The bracketed figures under (*e*) include the water soluble calcium and magnesium as well as the exchangeable.

TABLE III (*contd.*)

Sample No.	Depth of Layer in cms.	Ca Present as carbonate	Ca From Silicates	Mg From Silicates
(f) *More fertile soil taken a few metres from* (e)				
117	0–20	45.4	20.7	110.0
118	20–40	39.2	24.3	112.4
119	40–60	27.2	22.7	109.3
120	60–80	19.6	—	—
121	80–100	20.6	—	—
(g) *Profile of a gypsum bearing soil underlain by a sodium clay.*				
392 *A*	0–15	94.0	2.1	**175.9**
392 *B*	15–30	65.4	10.5	**175.1**
392 *C*	30–50	**122.4**	4.6	**126.6**

TABL IV.—ANALYSIS OF CLAYS.

Sample No.	Description of soil	SiO_2	R_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Ratio : $\frac{SiO_2}{R_2O_3}$	Relative Proportion of MgO
		%	%	%	%	%	%		
316	Basin land	44.06	33.19	11.51	1.10	4.41	2.42	1.33	2.88
—	Average of three other samples of basin land	41.74	32.23	11.14	1.06	3.83	2.43	1.30	3.03
391B	Fertile perennially irrigated land	38.47	29.46	—	—	5 38	2.47	1.31	3.26
76	" Black Alkali "	42.84	29.28	10.63	0.88	3.56	4.55	1.46	5.67
85	From profile (*d*) for comparison with 76 ...	42.54	30.22	11.19	0.92	3.43	3.77	1.41	4.72
112	From the profile of the gypsum-veined soil (*e*) of Tables I–III	40.46	29.94	—	—	4.67	2.83	1.35	3.63
113		38.52	27.63	9.96	1.20	4.49	2.72	1.39	3.71
114		43.66	31.34	9.89	1.14	3.54	3.00	1.39	3.68
392A	From the profile of the gypsum-bearing soil (*g*) underlain by sodium clay...	42.61	26.71	9.55	1.20	4.94	4.65	1.60	5.89
392B		42.90	27.12	9.76	1.26	4.88	5.07	1.58	6.34
392C		41.41	29.91	—	—	4.36	4.36	1.38	5.45

Note :—The figures given under " Relative proportion " of MgO were calculated as a percentage of $\frac{\%\ MgO}{\%SiO_2 + \%\ R_2O_3 + \%CaO} \times 100$

TABLE V.—ORGANIC MATTER OF "BLACK ALKALI." AND GYPSUM-VEINED SOILS.

Sample No.	Depth of Layer in cms.	Total Nitrogen %	Organic Carbon %	Ratio : Carbon / Nitrogen
(a) "*Black Alkali Soil.*"				
74	0– 15	0.042	0.372	8.9
75	15– 30	0.028	0.301	10.8
76	30– 55	0.023	0.239	10.4
(b) *More fertile soil taken near* (a).				
83	0– 20	0.070	0.891	12.7
84	20– 25	0.055	0.553	10.1
85	25– 55	0.041	0.372	9.1
(c) *Gypsum-veined soil.*				
112	0– 20	0.044	0.565	12.8
113	20– 40	0.030	0.473	15.8
114	40– 60	0.032	0.399	12.5
(d) *More fertile soil taken near* (c).				
117	0– 20	0.041	0.497	12.1
118	20– 40	0.033	0.447	13.6
119	40– 60	0.031	0.447	14.4

Govt. Press 4702 –1934–1065 ex.

MINISTRY OF AGRICULTURE, EGYPT.

Technical and Scientific Service

(Chemical and Agronomic Sections)

BULLETIN No. 152

An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt

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(Recommended for publication by the Publication Committee of the Ministry, which is not, as a body, responsible for the opinions expressed in this Bulletin)

Government Press, Bulâq, Cairo, 1935

Government Publications are on sale at the "Sale Room," Ministry of Finance. Correspondence relating to these publications should be addressed to the "Publications Office," Government Press, Bulâq, Cairo.

Price - - - - P.T. 10

CONTENTS

INTRODUCTORY

The reactions of the cotton plant to its environment in Egypt and the factors limiting its growth and yield have been extensively studied by Dr. W. L. Balls and the following analysis of the nature of the plant's response to manuring is best regarded as being a continuation of his work from the fertilising point of view. The main limiting factors of importance in the analysis are water strain and the nature of the season. As regards the former the most outstanding conclusion that Dr. Balls drew from his work was that "Water, always sufficient, but never excessive is the principal need of the crop"* and it will be shown that on the whole fertilisers can only exercise their effect strictly within the limits imposed by the physiologically available water. With regard to climatic effects it must be counted as exceptionally fortunate for the definition of the position (but not from the point of view of the grower) that the weather conditions in July and August, which are of critical importance, should have been as contrasted as they were in the years 1931 and 1933.

The data for the individual experiments on which the report is based are given in the tables in the appendix. In using the figures to illustrate any one aspect of the situation single results which are very widely divergent from the mean have occasionally been omitted. Thus, in calculating the total effect from added nitrogen for 1931, the experiment on basin land near Asyût of Table 6, in which only one picking was possible and in which consistent depressions in yield were occasioned by the treatments, was omitted since its inclusion would have given an unfairly low figure. Also the correlation coefficient of 0·31 for the 1932 cotton experiments between level of yield and response to nitrogen has been obtained by neglecting the one at Matâna where soil deficiency in nitrogen was extreme and yield effects from its application unusually great.

Examination of the results of the 1934 cotton experiments has confirmed all of the conclusions drawn in this report.

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* W. L. Balls "The Cotton Plant in Egypt." p. 88 (MacMillan & Co., 1912).

MINISTRY OF AGRICULTURE, EGYPT.

An Analysis of the Factors governing the Response to Manuring of Cotton in Egypt

Quantities of Fertilisers Imported.

Imports of artificial fertilisers into Egypt did not attain any considerable volume until after the war. In 1913 such imports were mainly accounted for by 56,000 tons of Chilean nitrate of soda, the next most important fertiliser being superphosphate (slightly over 13,000 tons). The amounts of potassic manures imported have always been negligible. After the war the rate of increase in the amount of artificial nitrogenous fertilisers imported was very rapid, the peak year so far being 1930 when they attained a figure of over 270,000 tons.* Superphosphate importations have also markedly gone up during this period although the quantity for any one year is much more variable. In view of the importance of the question from an economic point of view, field experimentation on a large scale has been undertaken by the Ministry of Agriculture to ascertain, if possible, the exact nature of the reaction of various crops to fertilisers. The period of rapid increase in the amounts of artificial nitrogenous fertilisers imported coincided with a period of high cotton prices. It is quite obvious that the expenditure of 100 kilos of nitrogenous fertiliser per feddan† to obtain an increase of a fifth of a kantar† of cotton can only be profitable during a period of high prices and opinion as to the utility of nitrogenous manures on cotton in particular was largely formed during such a period.

In the course of the past few years, therefore, increasingly large numbers of manurial and other trials have been carried out, mainly by the Agronomic Section, in all parts of the country. In particular the number of such experiments for the years 1931, 1932 and 1933 is sufficiently large as to represent, for each year, a fair sample of Egyptian agriculture as it actually is. The experiments have been

* This figure was much exceeded in 1934,

† *See* Note in Appendix.

carried out with various crops but are, as to a majority, naturally chiefly concerned with cotton and the analysis of the results will, therefore, principally be concerned with that crop. While the conclusions to be drawn are not final and further experimentation is necessary yet they are of a sufficiently fundamental character as to justify their publication. They enable the dimensions of the question of manuring agricultural crops in Egypt to be clearly stated, even although in some particulars they merely reaffirm or amplify work on the subject done in the past.

Conflicting Current Opinions.

This publication is particularly necessary in view of the conflicting nature of the opinions one hears expressed about the manuring of cotton. Thus one cultivator will maintain that nitrate up to six sacks per feddan is of benefit to the crop while another will be equally emphatic that even one sack is harmful. The six-sack man is naturally more talked about but does not for that reason represent the normal nor is his practice in general based on actual deliberate experiment. Others consider response to manuring to be a varietal charactersitic and accordingly uphold the opinion that Giza 7 is a variety which responds to manuring while Sakel does not. Still others maintain that it is a question of locality and that high nitrate manuring can only be successful in Upper Egypt, and so on. It will be shown from the nature of the results of the experiments that these and other, similar, partial statements have a basis in fact and that the conflict of opinion arises from a failure to give due weight to or to form a clear appreciation of the factors involved. In view of the existence of belief to the contrary it must in addition be stated that these experimental results also show it to be unlikely that any laboratory methods of estimating the manurial requirements of a soil (for cotton) will ever find practical application under Egyptian conditions (except possibly in the rare cases of extreme phosphate deficiency).

Previous Experiments.

The last extensive series of manurial trials on cotton of which the results have been published was carried out in 1908 by the late F. Hughes.* The conclusion he drew from the result of eleven experiments in the Delta was that, apart from one or two individual places,

* Year-Book of the Khedivial Agricultural Society, 1909.

manuring had, on the average, little or no effect on the *yield* of the cotton crop in Egypt. J. A. Prescott* also found at Bahtim, "a slight but positive effect on the yield in the case of the close spacing, but no effect whatever under ordinary conditions of cultivation, thus confirming the majority of field experiments on the manuring of the cotton plant in Egypt."

In the course of his report on his experiments Hughes remarks on the extremely variable nature of the soil in Egypt and says that the adoption of a different layout in the field (he used the strip system) would probably have led to more accurate results. At the same time his general conclusion as to the effect on manuring will be shown to be substantially correct although it would be better expressed by saying that, apart from one or two isolated cases the soil, regarded from the purely chemical point of view of nutrient supply cannot in any way be regarded *as a factor limiting the yield of cotton in Egypt*. As pointed out in the introduction the nature and intensity of the environmental factors which affect the growth and limit the yield of cotton in Egypt have already been extensively investigated by W. L. Balls whose work necessarily forms the background of the present report.

Aim and Design of the Present Experiments.

For the present series of manurial experiments the various environmental factors, such as soil (from the physico-chemical point of view), water supply, variety, spacing, sowing date, climate and nutrient supply will be strictly regarded as exerting their effect the one independently of the others. The assumption is that, either they are not capable of control, as with climate and the physico-chemical properties of the soil, or that, as with water supply etc. they are at optimum or near optimum level, an assumption which will be shown on the whole to be reasonably justifiable. The sole variant in an individual experiment for any one year, therefore, will be the manure supplied, while the soil factor will vary from experiment to experiment and the climatic one from year to year.

Under this assumption the main aim of the present series of manurial experiments† was that, for any one year, they should be sufficiently numerous and well distributed over the country for the results to be capable of statistical analysis and to be applicable to

* "Experiments on the Spacing of Crops." Bulletin No. 13 of the Sultanic Agricultural Society (1924), p. 47.

† The actual centres for the experiments, apart from the Ministry's farms, are changed as far as possible every year.

cotton growing in Egypt as a whole. As much, if not more, emphasis is laid on the actual number of observations as on the accuracy of the individual experiment. This last point has, however, in no way been neglected. From 1931 onwards the layout in the field has been increasingly that of randomised blocks for the larger experiments and of the Latin square for the smaller, so that the results can be treated statistically by the method of analysis of variance*. In addition the treatments adopted have always been such that the yields should be capable of showing a definite trend. The experiment carried out, for example, in Upper Egypt in 1933 (eleven centres) took the form of six randomised blocks with fifteen treatments giving a total of ninety plots. The treatments consisted in nitrogen at five levels (0,100,200,300 and 400 kilos of nitrate† per feddan) in combination with phosphate at three levels (0,100 and 200 kilos of 16–18 per cent superphosphate per feddan).

Error and Choice of Land.

Even with such arrangements the variability of the soil chosen for the experiment is occasionally so great as to dominate the result. In the experiments carried out at the Ministry's farm at Sids in Upper Egypt, where the land is known to have deteriorated, the error is always high and the effect of the treatments not significant; high experimental error is in fact always a feature of poor land. In view of this the choice of land for experiments is definitely made with a bias towards the better so that for each year the mean yield in the experiments is considerably greater than the general average for the whole country. The bearing of this selection on the results will be

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* *See* R. A. Fisher: "Statistical Methods for Research Workers." 2nd Edition (1928)

R. A. Fisher and J. Wishart: "The arrangement of Field Experiments and the Statistical Reduction of the Results." Imperial Bureau of Soil Science, Technical Communication No. 10 (1930).

L. H. C. Tippett, "The Methods of Statistics." (Williams and Norgate, 1931).

† The term nitrate is used here merely as being a convenient one. "A hundred kilos nitrate" or "one sack nitrate" or "I N" means a dressing of an artificial nitrogenous fertiliser supplying 15 1/2 kilos of nitrogen per feddan. Similary "I P" means a dressing of one hundred kilos of 16–18 per cent superphosphate per feddan.

From numerous trials carried out on the point it makes no *immediate* difference whether the nitrogen is supplied in the form of nitrate of soda, calcium nitrate, nitrochalk, sulphate of ammonia, etc.,—the only nitrogenous fertiliser in which the nitrogen is slightly less efficient than in others is tyanamide. Sufficient experiments have also been carried out to show that there is no significant advantage in splitting the higher of doses nitrogen, *i.e.* it is a matter of indifference whether a dressing of 300 or 400 kilos of nitrate is applied all at once or if half is given at thinning and half at the next watering (*see* experiments in Tables 4, 5, 8 and 9 of the Appendix).

considered later, but it must be kept in mind that these would undoubtedly have been more respresentative if the range of fertility of the land chosen could have been extended to include more of the less fertile. The mean experimental error (standard error or S.E.) in ninety-four experiments on the quantitative effect of nitrogen for the years 1931, 1932 and 1933 works out at :—

$$0.29 \pm 0.013 \text{ in kantars per feddan}$$

$$\text{or } 5.25 \pm 0.28 \text{ in per cent}$$

and if five experiments are excluded where the dispersion of the results is extremely high the mean percentage error sinks to 4.78 ± 0.22 which must be considered as satisfactorily low.

The Nature of the Effect of Treatments.

The main source of information available for the measurements of the effects of treatments is the fact that the crop has almost always been gathered in two pickings which have been separately weighed and recorded so that any alterations causd by manuring in the proportion of the crop obtained at the second picking can be followed. This main source of information can be supplemented in a few cases by flowering and bolling curves. Where the effect of a treatment (*e.g.* an application of nitrogen) is to cause an increase or amplification of the initial rise in the flowering and bolling curves the proportion of the crop at the second picking will remain the same or even diminish ; the nitrogen or other factor supplied will then be regarded as having been a limiting one on the particular soil on which the experiment was carried out. On the other hand where the same application of nitrogen in another experiment results in a deformation or prolongation of the flowering and bolling curves owing to the increased vegetative growth the proportion of the crop obtained at the second pick will increase to a greater or less extent irrespective of whether the total yield is increased or not. In this latter case, although the total positive effect experienced in the yield may be considerable, the nature of the reaction must be sharply distinguished from the former and the nitrogen or other factor causing it cannot be regarded as a limiting one in the same sense.

The point of view developed above is very well illustrated by flowering curves obtained in a manurial experiment at Gimmeiza in 1933 (*see* Figs. 1 and 2). The main result of the application of 100 kilos of nitrate is a sharp increase in the maximum of the flowering curve ; when the 300 kilos application, however, is reached the maximum of the flowering curve is almost the same as for the control plots but the curve is markedly extended. When these three sacks are balanced by a dressing of superphosphate the flowering curve goes back to its " normal " form and has the highest maximum of all. The actual yield figures from these treatments in the experiment, together with the proportion of the crop obtained at the second picking, are given below :—

GIMMEIZA 1933

Treatments	O	1N	2N	3N	3N+1P	S.E.
Yields per feddan in kantars* ...	5.27	6.07	6.99	7.09	7.79	0.18
Percentage of crop at 2nd picking	64.7	68.7	70.0	75.5	74.7	—

As would be expected from the flowering curves, the only effect of the three hundred kilos of nitrate as compared with two hundred is to cause a further increase in the proportion of the crop obtained at the second picking, the total yield remaining unaltered. When these three hundred kilos of nitrate are accompanied by a hundred kilos of superphosphate there is a significant increase of 0·70 of a kantar over the nitrate given alone while the proportion of the crop obtained at the second pick is the same.

In what follows the effect of the various factors of water supply, spacing, soil, climate, etc., will be considered consecutively and separately in relation to manuring. Alterations in the first two factors have been occasioned by :—

RECENT ALTERATIONS IN THE TYPE OF COTTON PLANT CULTIVATED.

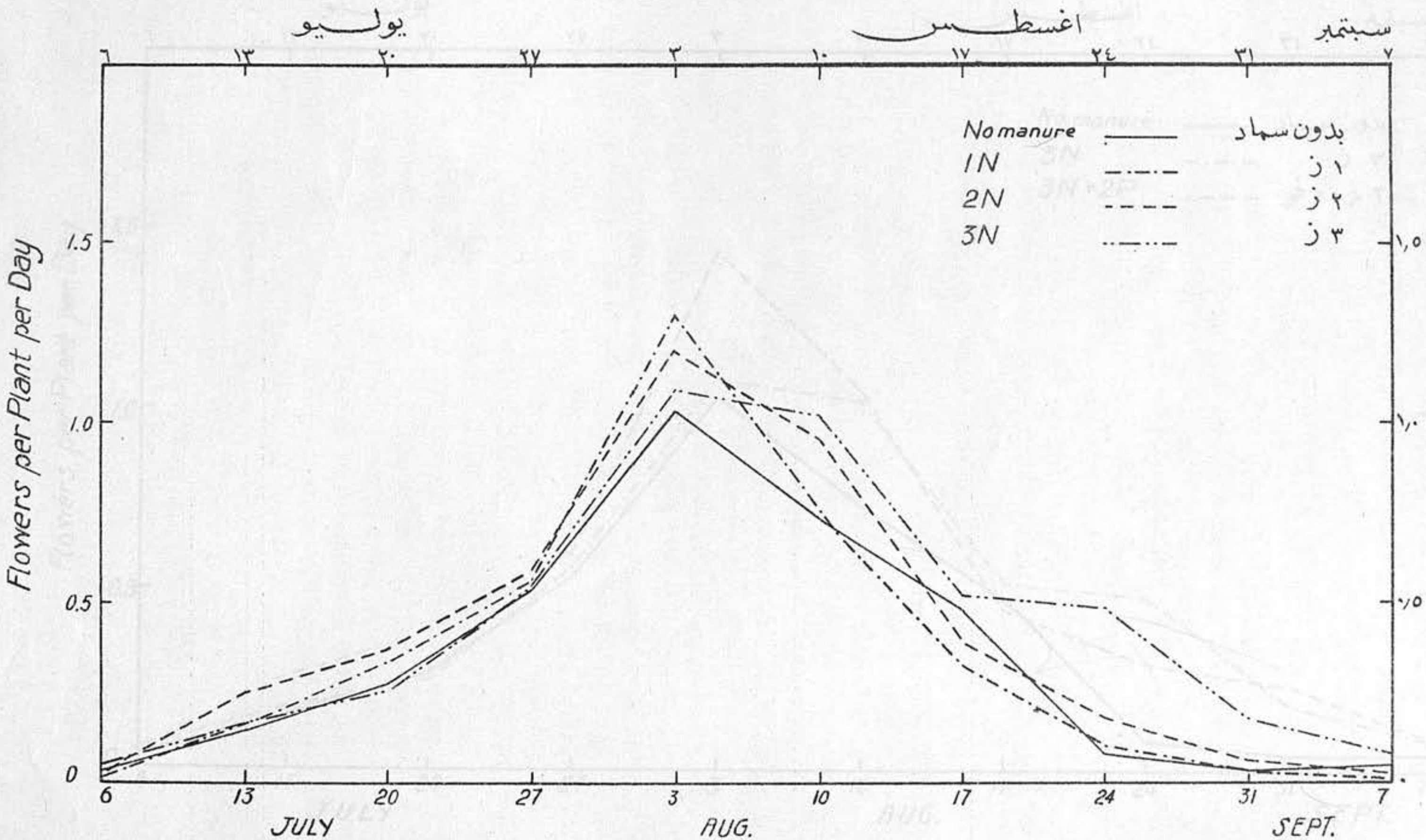
The necessity for regarding the crop from the above point of view is decided by the changes which have occurred in the past twenty years in the type of plant cultivated. Owing to the advent of the pink bollworm the effective growing period of the plant has been considerably shortened. This in turn has entailed revision of the questions of sowing date, optimum spacing and watering practice ; anything in fact which tends to produce an

* Results are given in kantars per feddan of seed cotton—*see* Note in Appendix.

Fig. 1

NITROGEN and PHOSPHATE EXPERIMENT
at GIMMEIZA 1933
Flowers per Plant per Day

تجربة الازوتات والفسفات
بالجميزة سنة ١٩٣٣
عدد الازهار على النبات الواحد في اليوم



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٠/٢٥٣)

NITROGEN and PHOSPHATE EXPERIMENT

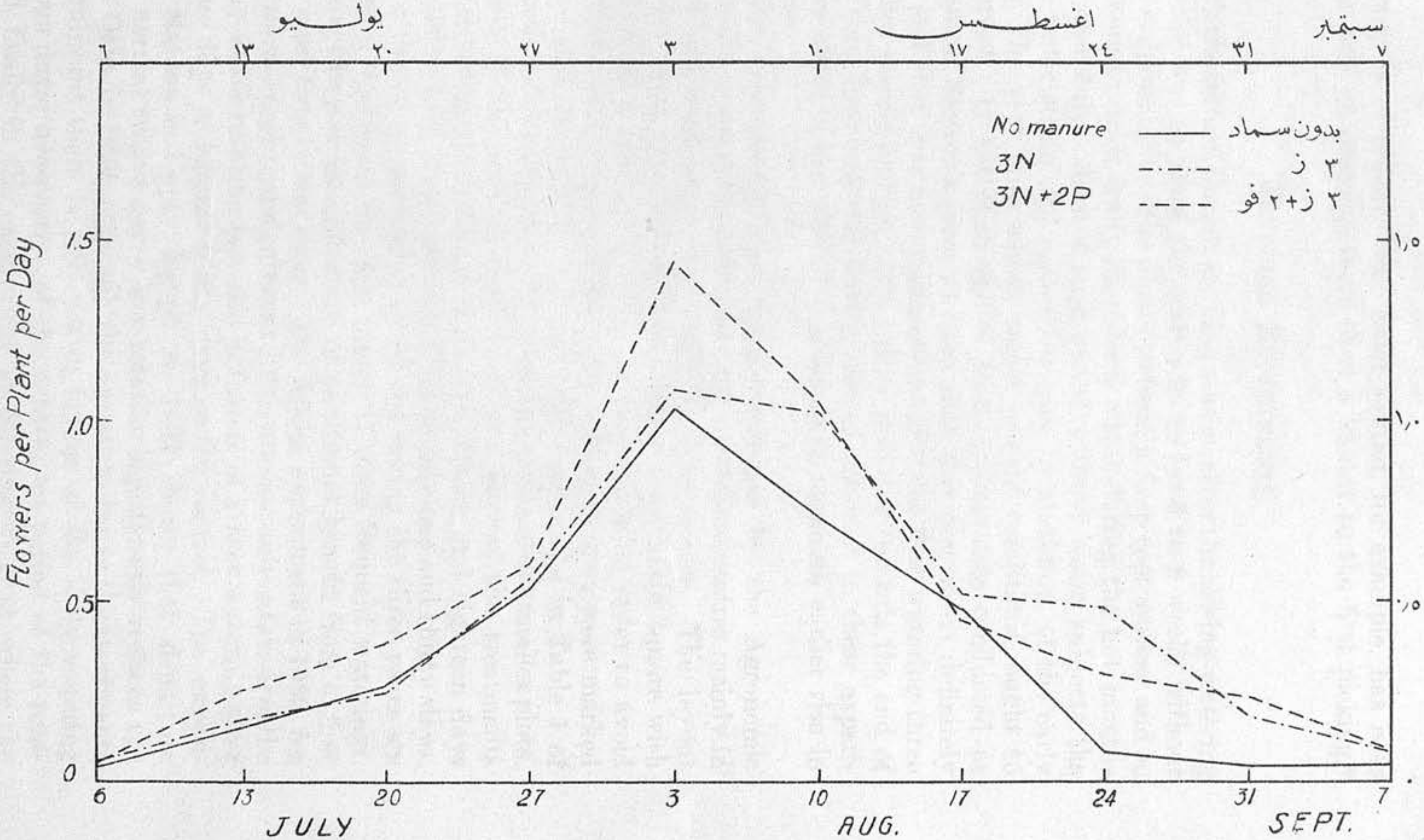
at GIMMEIZA 1933

Flowers per Plant per Day

جـربـة الازوتات والفسفات

بالجميزة سـنة ١٩٣٣

عـدد الازهار على النبات الواحـد فى اليوم



مصلحة المساحة المصرية سنة١٩٣٥ (٣٠/٢٥٣)

earlier crop is of importance. Sand sowing, for example, has been shown to add on occasion more than a kantar to the first picking.*

Watering Experiments.

With the former, longer, growing season after the sowing-watering the practice was to allow the cotton to go for 6 to 8 weeks without water in order to induce the plants to form a deep root system and so enable them to draw freely on subsoil water during the hot months of June and July. Such a long period without water subjects the plant to water strain and causes the loss, by shedding, of the early buds, *i.e.* the very ones which, under present conditions, ought to be preserved. It has been shown from experiments conducted at the Botanical Section's farm at Giza that this practice is definitely harmful and that it is now necessary to give the first watering three weeks after sowing and an extra heavy watering towards the end of June. From flowering and bolling curves obtained in these experiments the effect of the altered practice is to cause an earlier rise in the curves.

Similar experiments have been conducted by the Agronomic Section in the years 1931, 1932 and 1933 at various centres mainly in the Delta and confirm, on the whole, the Giza results. The layout adopted for these experiments was a seven-sided Latin square with plots 1/20th of a feddan in area. In harvesting, in order to avoid border effects, central plots 1/40th of a feddan in area were marked out within each larger plot, and the results presented in Table 1 of the appendix have been calculated from the yields of the smaller plots. In addition to the normal practice of the district the treatments included watering rotations every twelve, fifteen and eighteen days in combination with first waterings after twenty-one and thirty days.

Of the fourteen experiments carried out during the three years six have given a significant result in favour of more frequent waterings. Of these six, five give an indication of additional benefit from a first watering after twenty-one days. The Sakha experiment of 1932, for example, shows consistent significant differences not only in favour of the twelve-day water rotation but also in favour of a first watering after twenty-one days as against thirty days or the control. The experiment at Matâna in Upper Egypt in 1933 shows that departure from the normal twelve-day water rotation significantly reduces the yield ; at Qaha in 1932, although the variation due to the treatments is not significant, there is evidence in favour of the early watering (twenty-one days) irrespective of the subsequent period of the rotation ; and finally in the experiment at Sibirbai in 1933, where the

* J. Templeton : " Sand sowing of Cotton Seed." Empire Cotton Growing Review (1932)

treatments are again not statistically significant, there is an indication that (the cotton was grown after berseem preceded by rice) watering oftener than at eighteen-day intervals is detrimental. The cotton in the remaining five experiments appeared to be indifferent to the variations in its water supply and there is no evidence of reaction.

The extent of the positive effect may be considerable and ranges in the experiments showing significant response from 1·14 kantars per feddan at Abu Raqaba in 1931 and Gimmeiza in 1932 to over 2 kantars at Sids in 1933. Since these increases in yield are accompanied by a decreased, or at least unaltered, proportion of the crop at the second picking, the effect of the more frequent watering has been to cause, as at Giza, an earlier rise or a higher maximum of the flowering curve. At the centres giving significant positive results irrigation practice has therefore been a factor limiting the crop.

Regarding the watering experiments as a whole it is clear that, as would naturally be expected, the best watering practice varies from place to place. It is well known for example that for successful cultivation in salty lands in the North of the Delta more frequent and heavier waterings than elsewhere are necessary and of course in the hotter conditions of Upper Egypt water at shorter intervals than in Lower Egypt is given. Even where a more frequent water rotation has been shown to be of benefit, however, other considerations must come in before it can be adopted. One of the causes of soil deterioration in Egypt is undoubtedly over-watering (in the absence of drainage) in relation to the physical nature of a soil; once deterioration has set in still heavier watering is necessary to offset its effects, with the inevitable result of making matters still worse. These, and other, considerations do not, of course, apply to the long intervals (periods of forty-five days are very common) which are still frequently allowed to intervene between the sowing and first waterings, and the original reasons for which no longer exist. In discussing the results of the manurial experiments the question of watering practice will again be referred to since it may obviously be a factor determining the level of yield.

Spacing Experiments.

Twenty years ago, when the picking of the crop was sometimes continued well on into December and even January, the maximum yield was obtained with a spacing* of 75 centimetres between the ridges and 45 centimetres between the holes with two plants per hole.

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* W. L. Balls and F. S. Holton. Phil. Trans., Royal Society, London, Series B, 206, 103 (1915).

Under the new conditions created by the pink bollworm, experiments * carried out at Giza have shown the optimum spacing to be a closer one —the conclusion being that, in round figures, the optimum spacing is now 65 centimetres between the ridges and 35 centimetres between the holes, again with two plants per hole. The necessity for this closer spacing has been fully confirmed by further experiments carried out by the Agronomic Section. In the manurial experiments the normal spacing employed has been an even closer one— 65 centimetres between the ridges (*i.e.* eleven ridges per two kassabas) and 25–30 centimetres between the holes. A greater number of ridges than eleven per two kassabas is not practicable on account of the resulting injury to the plants during cultivation operations.

Reaction between Spacing and Manuring.

A marked reaction between spacing and manuring can only be expected on soils deficient in plant nutrients. The spacing experiments referred to above have all been carried out under optimum or near optimum conditions for nutrient supply ; on the Botanical Section Farm at Giza, for example, the level of soil fertility is so high that manuring has little or no effect on the yield of cotton grown there at any spacing.

Owing to the importance, however, of any such possible interaction field experimentation on an extensive scale was undertaken on this point in 1931 and 1932. The type of experiment adopted took the form of nine blocks with twelve plots per block and the treatments the various combinations of three varieties, three spacings and two levels of nitrogen. In order to reduce the labour involved each block was wholly devoted to any one spacing, there being therefore three blocks for each spacing with two replications of the variety and manuring combinations within each block. As a result of this arrangement soil variation has been confounded to some extent with spacing effect so that it would be dangerous to draw any rigid conclusion from an individual experiment. This loss in accuracy in the individual experiment has been offset by the greater number of them possible the experiment was carried out at twelve centres in 1931 and at thirteen in 1932. The levels of nitrogen adopted were 100 and 200 kilos. of nitrate † per feddan in Lower Egypt and 150 and 300 kilos in Upper Egypt (100 kilos nitrate supplying $15\frac{1}{2}$ kilos nitrogen per feddan). The spacings employed were 10,11 and 12 ridges per

* J. Templeton, " Watering and Spacing Experiments with Egyptian Cotton." Bulletin No. 112 of the Ministry of Agriculture, Egypt.

† *See* foot-note 2, page 4.

two kassabas with 25–30 cms. between the holes, the normal spacing being, as already pointed out, 11 ridges per two Kassabas. The varieties employed naturally varied with the locality of the experiment. The results of the individual experiments are given in Tables 2 and 3 of the appendix; in the summary of the results presented below varietal effect has been disregarded since the main concern here is interaction between spacing and manuring.

AVERAGE OF ALL VARIETIES FOR LOWER EGYPT FOR 1931 *
(24 observations).

Spacing in ridges per two Kassabas †	10	11	12
Nitrogen Level ... ... 100 kgs.	4.92	5.05	5.06
200 kgs.	5.18	5.20	5.38
Difference in favour of higher nitrogen	+0.26	+0.15	+0.32

AVERAGE OF ALL VARIETIES FOR UPPER EGYPT FOR 1931
(9 observations).

Spacing in ridges per two kassabas	10	11	12
Nitrogen level ... ... 150 kgs.	4.65	4.33	4.62
300 kgs.	5.06	4.59	4.82
Difference in favour of higher nitrogen	+0.41	+0.26	+0.20

AVERAGE OF ALL VARIETIES FOR LOWER EGYPT FOR 1932
(26 observations) §

Spacing in ridges per two kassabas	10	11	12
Nitrogen level ... ... 100 kgs.	5.67	5.88	5.90
200 kgs.	6.05	6.41	6.20
Difference in favour higher nitrogen	+0.38	+0.53	+0.30

AVERAGE OF ALL VARIETIES FOR UPPER EGYPT FOR 1932
(12 observations)

Spacing in ridges per two kassabas	10	11	12
Nitrogen level ... ... 150 kgs.	7.10	6.94	6.92
300 kgs.	7.23	7.26	7.05
Difference in favour of higher nitrogen	+0.13	+0.32	+0.13

* All yields are in Kantars per feddan of seed cotton.
† See note in Appendix.
§ One very irregular result obtained with Ashmouni Gedid at Qaha has been omitted.

The mean differences between spacings at the two nitrogen levels and the mean differences between the nitrogen levels at the different spacings for Lower Egypt are set out below in kantars per feddan :—

MEAN DIFFERENCES BETWEEN SPACINGS AT THE TWO NITROGEN LEVELS.

Year	**1931** (24 Observations)		**1932** (26 Observations)	
Nitrogen level	Difference between 10–11 ridges	Difference between 11–12 ridges	Difference between 10–11 ridges	Difference between 11–12 ridges
100 kilos ...	+0.14±0.065	+0.03±0.065	+0.20±0.065	+0.02±0.056
200 kilos ...	+0.03±0.047	+0.17±0.080	+0.36±0.059	—0.20±0.095

MEAN DIFFERENCES BETWEEN NITROGEN LEVELS AT THREE SPACINGS.

Year	**1931** (24 Observations)	**1932** (26 Observations)
Spacing in ridges per two kassabas	Mean differences between nitrogen levels	Mean differences between nitrogen levels
10	+0.26±0.067	+0.38±0.072
11	+0.15±0.064	+0.49±0.053
12	+0.32±0.067	+0.26±0.074

If the results are taken as a whole in this manner there is no significant reaction in Lower Egypt in 1931 between spacing and manuring nor any significant differences between spacings. At the same time a distinct trend is shown by the results, at both levels of Nitrogen, in favour of the closest spacing. The results for Upper Egypt are too irregular to allow of any conclusions being drawn.

In Lower Egypt in 1932 while there is still no significant positive interaction between spacing and manuring there is a significant decrease of 0·23 ±0·091 kantars per feddan in the mean difference between the nitrogen levels at the closest spacing *i.e.* at the higher nitrogen level twelve ridges per two kassabas is too close and the yield is reduced while it remains stationary at the lower nitrogen level. The trend of the results for Upper Egypt also bears out this finding.

The conclusion therefore is that in 1932 *with high nitrogen manuring a spacing closer than eleven ridges per two kassabas is detrimental while in* 1931 *the closest spacing, irrespective of manuring, tended to give the best result.* In treating the results of the manuring experiments later it will be shown that this seasonal effect is of the first importance and really bears on nitrogen response ; in 1932 in Lower Egypt the yield differences between the nitrogen levels in these spacing experiments are greater than in 1931, *i.e.* nitrogenous manuring was much more effective in the former year. In the meantime, as already stated, the necessity for a closer spacing than before the war is best regarded as being determined solely by the necessity for an earlier crop and the spacing of eleven ridges per two kassabas with 25–30 centimetres between the holes employed in the manurial experiments as on the whole reasonably near the optimum, and independent of the manure supplied.

Manurial Experiments.

The most immediately striking feature of the results of the manurial experiments is the consistent parallelism shown by the curves of Figs. 3–7 in which yields per feddan have been plotted against the treatments with which they were obtained for various varieties in three years. It is particularly marked in 1933 and 1932 but is much less so in 1931, the reason for which will appear later. This parallelism means that the level of yield of cotton in Egypt is primarily determined by factors other than fertilisers and is the direct reflection of the actual variation in the intensity of these factors as one moves from centre to centre at which the experiments were carried out. Fertilisers must therefore be regarded as secondary in effect ; they may, and do, cause important increases in yield but only within *the limits imposed by the factor or factors determining the yield level.* The only indication of nutrient supply being a limiting factor in the ordinary sense is given by a few exceptional experiments ; at Qaha in 1931, nitrogen applications increased the yield of Fouadi from 2·65 to 5·11 kantars per feddan and at Matâna in 1932 the yield of Giza 7 from 1·97 to 8·04 kantars while in the experiment at Sakha in 1933 phosphate deficiency was a limiting factor. These increases from nitrogen at Qaha and Matâna were obtained with actual decreases in the proportion of the crop obtained at the second picking. Such cases are, however, definitely exceptional.

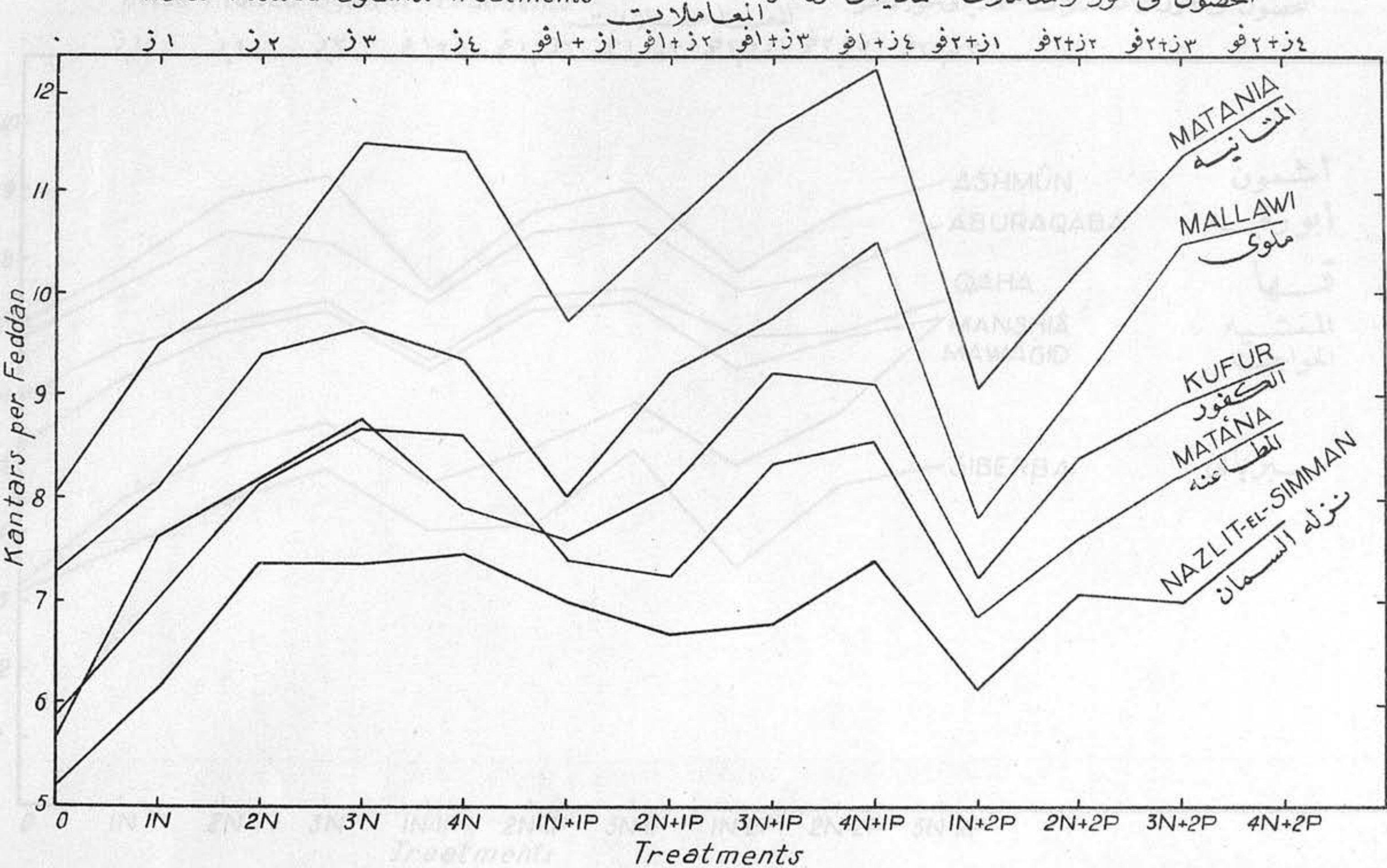
MANURIAL EXPERIMENTS
تجارب التسميد

with ASHMOUNI GEDID in UPPER EGYPT in 1933

على صنف الأشمونى الجديد بالوجه القبلى سنة ١٩٣٣

Yields Plotted against Treatments

المحصول فى محور والمعاملات السماديه فى المحور الأخر



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٠/٢٥٣)

MANURIAL EXPERIMENTS

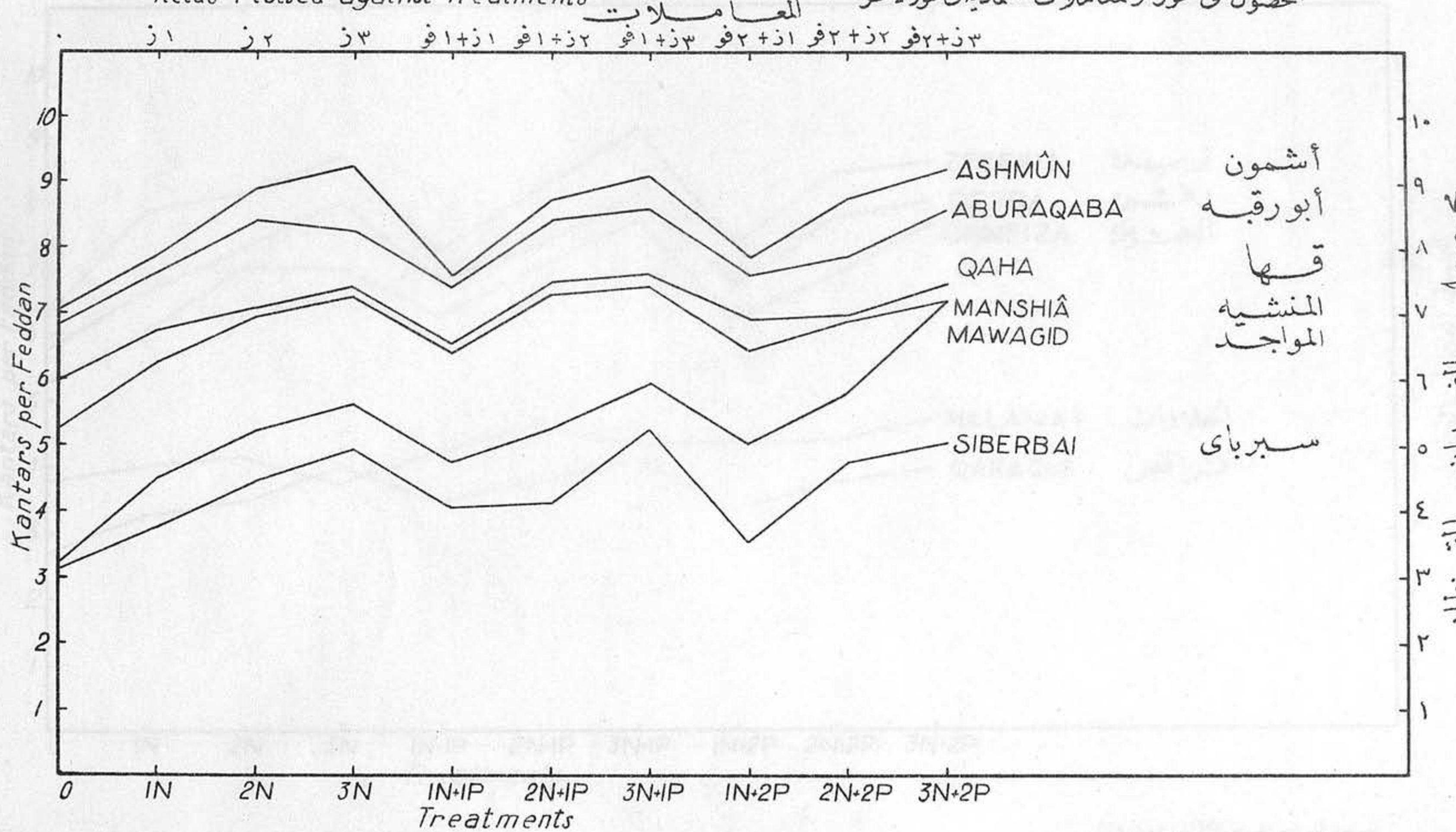
with ASHMOUNI GEDID in LOWER EGYPT in 1933

Yields Plotted against Treatments

تجارب التسميد

على صنف الأشموني الجديد بالوجه البحري سنة ١٩٣٣

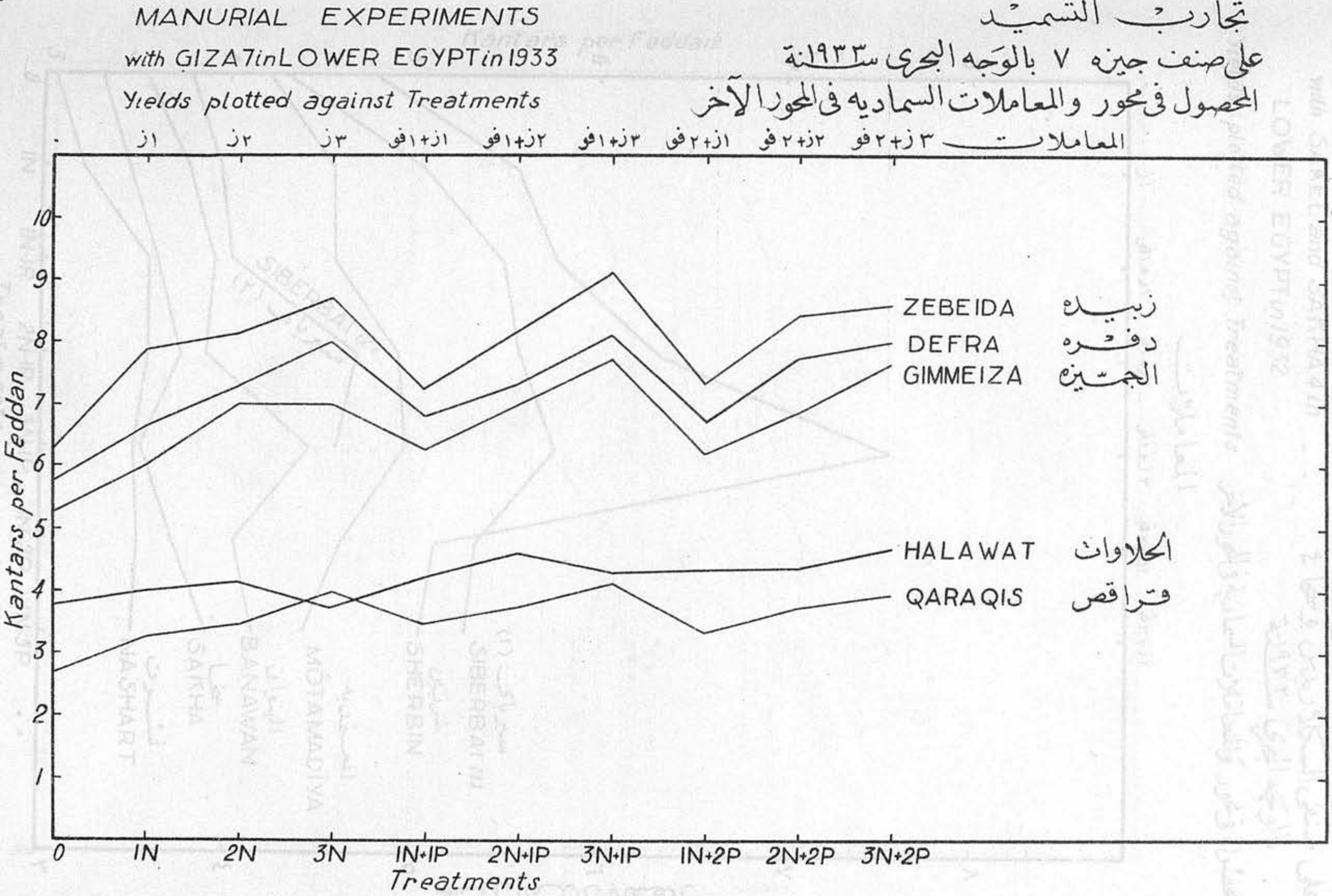
المحصول في محور والمعاملات السمادية في المحور الأخر



مصلحة المساحة المصريه سنة ١٩٣٥ (٣٠/٢٥٣)

Fig. 5

شكل رقم ٥



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٥/٢٥٣)

Fig. 6

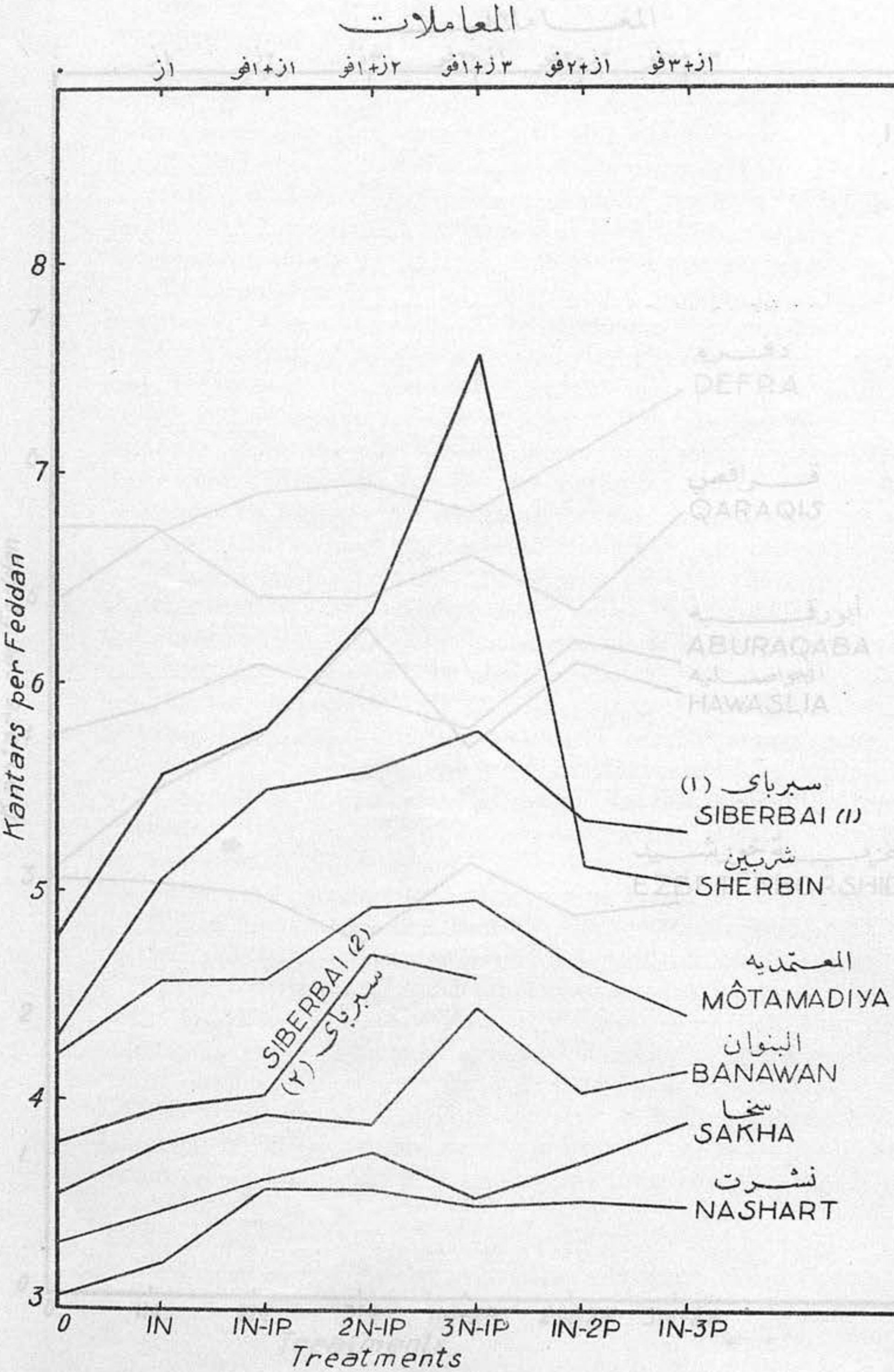
شكل ٦

MANURIAL EXPERIMENTS with SAKEL and SAKHA 4 in LOWER EGYPT in 1932

تجارب التسميد على صنفى السكلاريدس وسخا ٤ بالوجه البحري سنة ١٩٣٢

Yields plotted against Treatments

المحصول فى محور والمعاملات السمادية فى المحور الاخر



مصلحة المساحة المصرية ١٩٣٥ (٣٥/٢٥٣)

Fig. 7

شكل رقم ٧

MANURIAL EXPERIMENTS

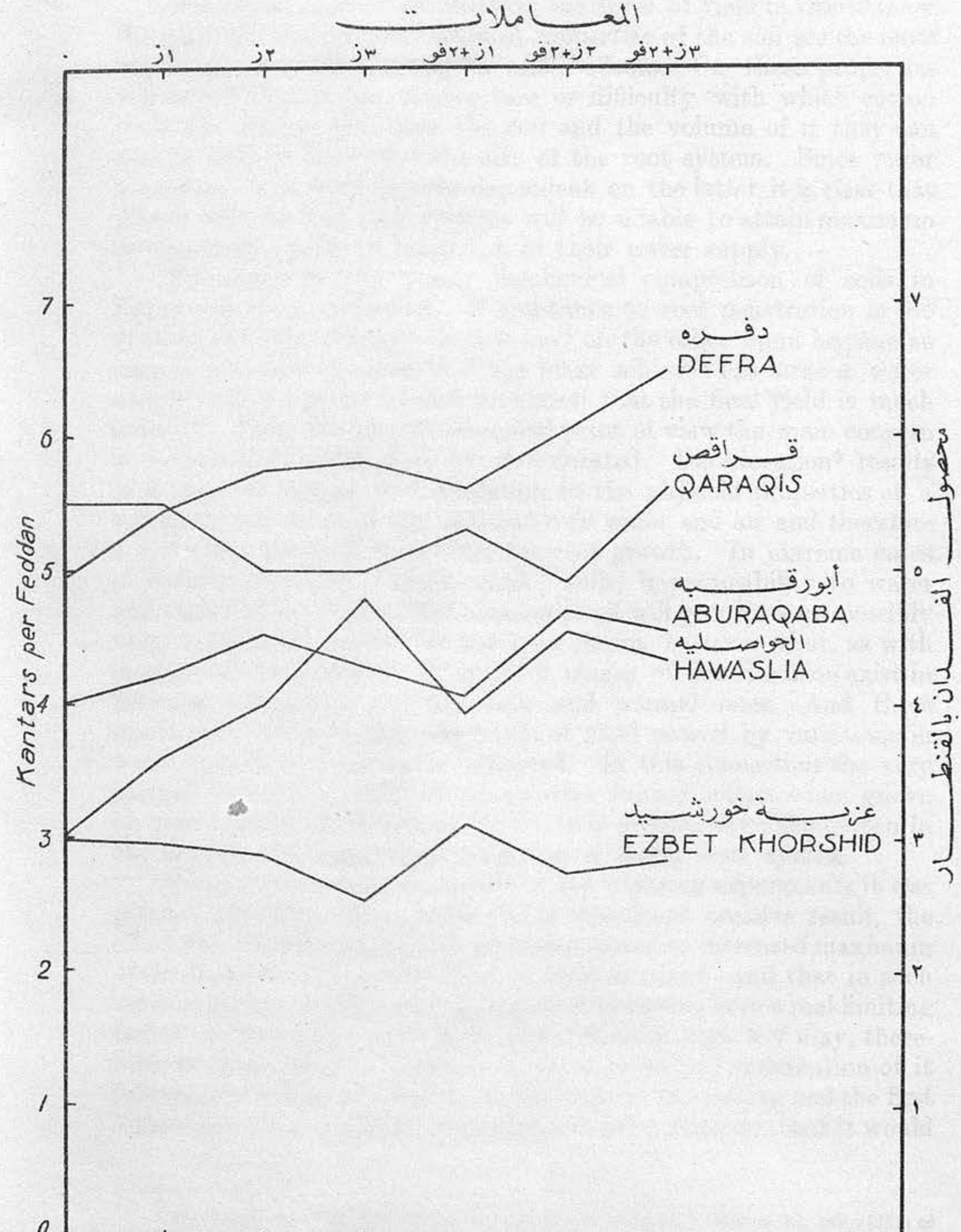
with GIZA 7 in 1931

Yields plotted against Treatments

تجارب التسميد

على صنف جيزة ٧ سنة ١٩٣١

المحصول فى محور و المعاملات السمادية فى المحور الآخر



مصلحة المساحة المصرية ٣٥/٢٥٣ ١٩٣٥

Soil Factors Limiting the Level of Yield.

Among the factors determining the level of yield in this manner the physical and physico-chemical properties of the soil are the most important and far-reaching in their effects. On these properties will largely depend the relative ease or difficulty with which cotton roots are able to penetrate the soil and the volume of it they can occupy and so determine the size of the root system. Since water absorption is in turn directly dependent on the latter it is clear that plants with limited root systems will be unable to attain maximum development owing to limitation of their water supply.

Variations in the purely mechanical composition of soils in Egypt can be considerable. If resistance to root penetration is too great in the case of heavy clays it may on the other hand become so easy in the case of sands that the plant achieves too large a water supply and overgrows to such an extent that the final yield is much reduced. From the physico-chemical point of view the main concern is the extent to which a soil has deteriorated. Deterioration* results in a more or less marked alteration in the physical properties of a soil so that it becomes less permeable to water and air and therefore a much less favourable medium for root growth. In extreme cases of deterioration (*e.g.* " black alkali " soils) impermeability to water and air becomes so great that nothing at all will grow (except possibly some xerophytic weeds). It has been shown, however, that, as with mechanical composition, all sorts of stages of deterioration exist in between completely infertile soils and normal ones. And these stages will represent different levels of yield caused by variations in water supply in the manner indicated. In this connection the very marked increase in yield of ratoon over annual cotton when grown on poor soils in the North of the Delta is noteworthy ; the cotton in the second and succeeding years has a better root system.

When dealing with the results of the watering experiments it was pointed out that, where there was a significant positive result, the effect was experienced through an earlier rise or an increased maximum of the flowering curve—the level of yield is raised—and that in such cases irrigation practice must be regarded as having been a real limiting factor on the crop. Part of the parallelism in Figs. 3–7 may, therefore, be due either to insufficient water or to bad distribution of it (allowing too long a period to elapse between the sowing and the first waterings). It must again be emphasised here, however, that it would

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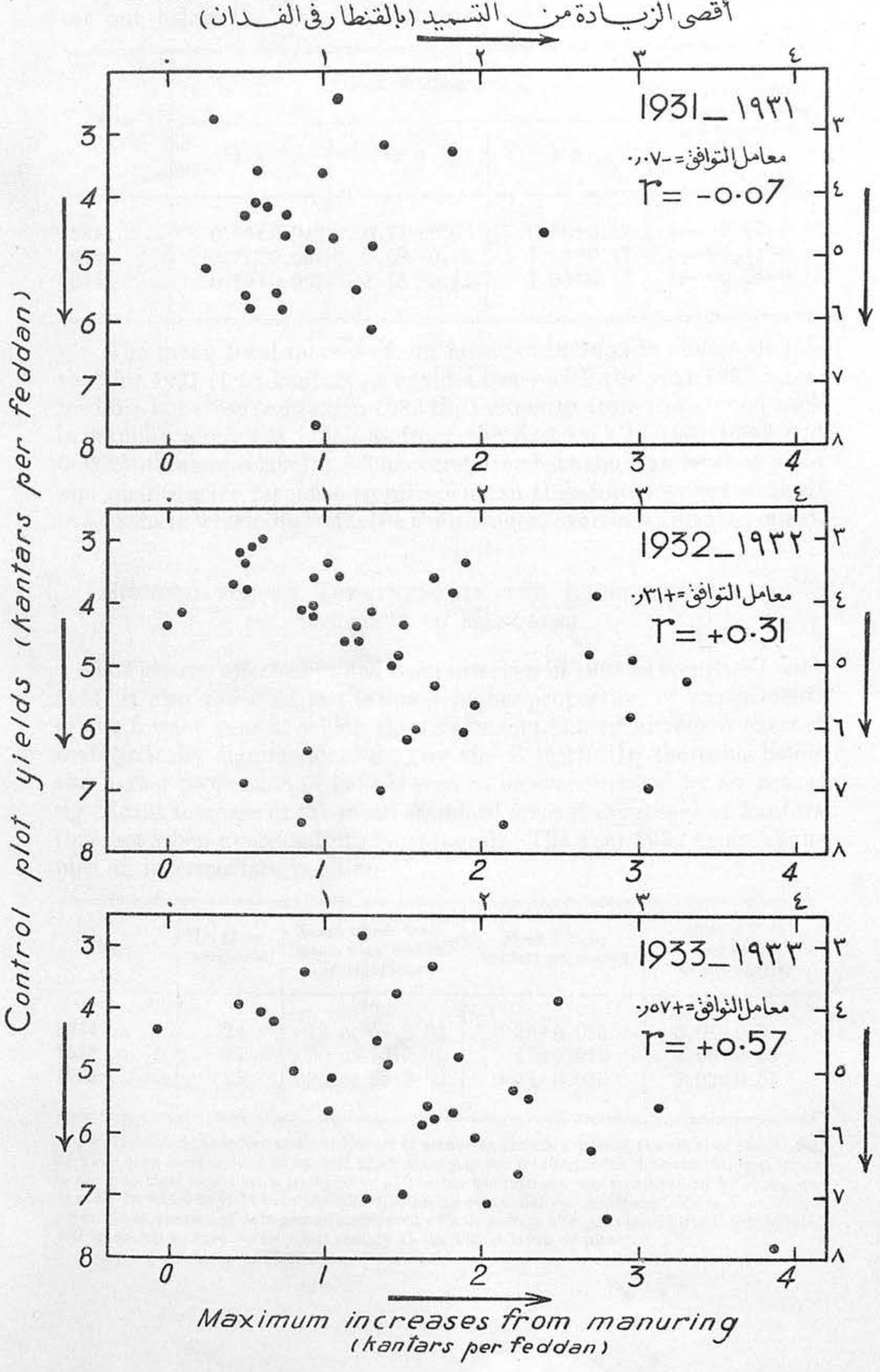
* For details *see* " The Nature of Soil Deterioration in Egypt." Bulletin No. 148 (1934) of the Ministry of Agriculture, Egypt.

شكل رقم ٨

Fig. 8

RELATION between CONTROL PLOT YIELD and RESPONSE to MANURING

العلاقة بين محصول قطع المقابلة والاستجابة للتسميد



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٥/٢٥٣)

at three successive levels of nitrogen for each of the three years are set out below in kantars per feddan* :—

Year	Level of nitrogen			Correlation coefficient between yield level and response to manuring
	1 N	2 N	3 N	
1931... ...	0.53±0.048	0.74±0.08	0.86±0.12	r=−0.07±0.21
1932... ...	0.71±0.067	1.08±0.12	1.39±0.17	r=+0.31±0.16
1933... ...	0.75±0.067	1.18±0.12	1.53±0.16	r=+0.57±0.18

The mean total increase from nitrogen in 1933 is almost double that for 1931 (1·53 kantars as against 0·86) with the year 1932 intermediate but close to 1933; in 1933 the increment from the second sack is actually almost as much as from the first sack in 1931 (0·43 and 0·53 kantars respectively). The correlation between high level of yield and quantitative response to nitrogen can therefore only reveal itself in seasons in which the latter (*i.e.* the nitrogen) exercises a marked effect.

Significance of Treatment in the Experiments and Response to Manuring.

The greater effect obtained from nitrogen in 1933 as compared with 1931 is also reflected in the much higher proportion of experiments in the former year in which the treatments (added nitrogen) exerted a statistically significant effect (by the Z test). In the table below this higher proportion of 1933 is seen to be accompanied by an actual significant increase in the mean standard error if expressed in kantars (but not when expressed in percentages). The year 1932 again occupies an intermediate position.

Year	No. of experiments	No. in which treatments were statistically significant	Mean S.E. in kantars per feddan	Mean S.E. in per cent of mean yields
1931	24	13 or 54.2 %	0.25±0.025	5.04±0.64
1932	41	30 or 73.2 %	0.27±0.019	4.96±0.35
1933	29	24 or 82.8 %	0.33±0.023	5.92±0.53

* These and other figures for the effect of manuring include a part of the effect of phosphate, *i.e.* they have been arrived at by first of all averaging the results for the different nitrogen levels in the individual experiments irrespective of whether the nitrogen was accompanied by phosphate or not. Increases in yield from phosphate, although occasionally a significant feature of individual experiments, are negligible in amount compared with those from nitrogen ; in addition it (phosphate) will be shown to exercise its effect mainly at the higher levels of nitrogen.

Correlation between Total Response to Nitrogen and increased Proportion of the Crop at the Second Picking.

The seasonal variation in response to nitrogen can be further analysed by making use of the figures for the proportion of the crop obtained at the second picking. The actual order of magnitude of these figures in the individual experiment is naturally determined by the date of the first picking but alterations in the proportions caused by manuring will remain irrespective of that date. The mean differences in the proportion of the crop obtained at the second picking as one moves from nitrogen level to nitrogen level have therefore been extracted and are presented below, *i.e.* mean total *increases* in the percentage of the crop obtained at the second picking in moving from :—

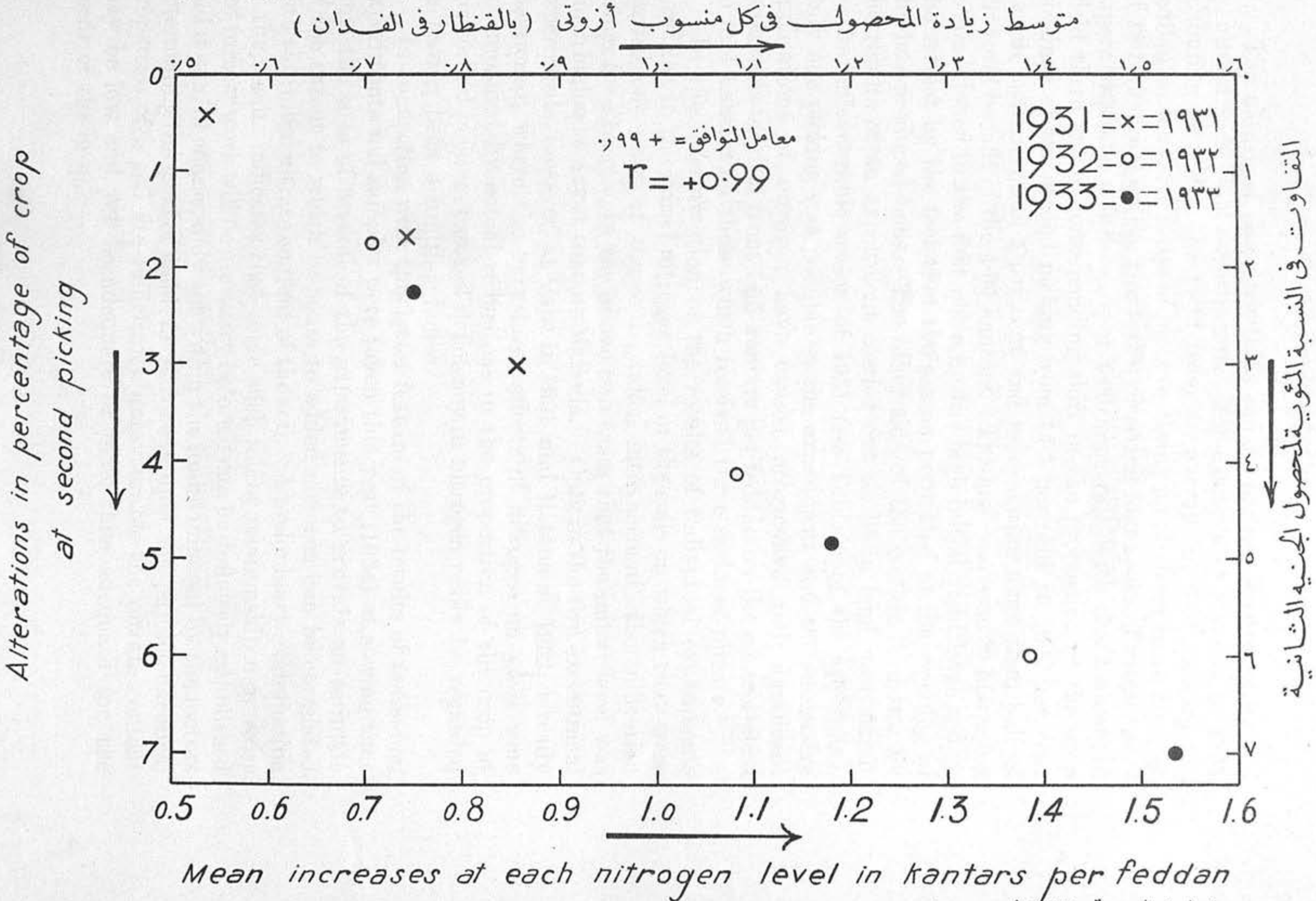
Year	0 — I N	0 — 2 N	0 — 3 N nitrogen level
1931...	0.4%±0.45	1.6%±0.46	3.0%±0.55
1932...	1.7%±0.42	4.1%±0.57	6.0%±0.82
1933...	2.3%±0.56	4.8%±0.83	7.0%±0.97

And it is immediately evident that the high total response to nitrogen in 1933 is strongly associated with the increased proportion of the yield obtained at the second picking. This correlation is illustrated in Fig. 9 which has been drawn from the above figures; it is significant and complete ($r=+0{\cdot}99 \pm 0{\cdot}35$). The large reaction to nitrogen in 1933 as compared with 1931 is therefore clearly due to the fact that more of the late bolls were ripened in the former year. *If the experiments are taken as a whole* nitrogen in them can only be regarded as a real limiting factor on the crop to the extent of roughly rather less than the half-kantar per feddan which was obtained in the 1931 experiments with one sack of nitrate; this half-kantar is taken to represent the mean extent of nitrogen deficiency in the soils on which the experiments were carried out and as being, therefore, a permanent effect probable in any year. Further applications of nitrogen after the first sack always cause a progressive distortion or prolongation of the flowering curve owing to the increased vegetative growth. The proportion of the resulting additional bolls on these larger plants which ripen depends on the season; in 1931 they were mostly shed but in 1932 and especially in 1933 they tended to ripen and were picked.*

* The results for the years 1932 and 1934 also show that yield effects from manuring (or ripening of the late-formed bolls) may depend to some extent on earliness is sowing. The association is not very marked and attained a bare significance only in the latter year ($r = + 0.39 \pm 0.20$). The influence of sowing-date must in any case be complex and be largely made up of unavoidable locality, varietal and climatic effects.

RELATION between YIELD EFFECTS from MANURING and INCREASE in PROPORTION of CROP at the SECOND PICKING

العلاقة بين تأثير التسميد فى محصول القطن والزيادة فى نسبة الجنيه الثانية



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٥/٢٥٣)

The nature of these reactions can be further illustrated by the results of *individual* experiments. For example at Matania in 1933 manuring increased the yield from an average of 8·07 kantars per feddan on the three series of plots receiving no nitrogen to an average of 12·13 kantars on the two series receiving four sacks of nitrate plus superphosphate, a difference of 4·06 kantars. With this increase in yield there was a corresponding shift in the proportion of the crop obtained at the second picking from 14·3 per cent to 30·8 per cent *i.e.* an increase of 16·5 per cent and representing more than half of the total benefit of the 4·06 kantars. The high response to manuring is conditioned in the first place by the high initial yield level and in the second by the fact that the season permitted of the ripening of the late-produced bolls. The other side of the picture is shown by the results of an experiment carried out on basin land near Asyût in the unfavourable season of 1931 (*see* Table 6 of the appendix). Only one picking was possible in the experiment and the successive applications of nitrogen have caused progressive and significant reductions in yield from 7·65 kantars per feddan on the control plots to 5·14 kantars on those which received three sacks of nitrate.

In the interpretation of the results of individual experiments variation in the initial nitrogen level of the soils on which they were carried out must of course be taken into account, the indication being, for example, in the above two cases that the initial level was much higher at Asyût than at Matania. Only in the two exceptional experiments, however, at Qaha in 1931 and Matâna in 1932, already mentioned, where the very large effects of nitrogen on yield were accompanied by actual reductions in the proportion of the crop at the second picking, can soil deficiency in nitrogen really be regarded as having been a limiting factor.

In connection with this latter feature of the results of *individual* experiments soil samples were taken this year (1934) at sowing time from the sites of several of the experiments to provide an estimate of the extent to which response to added nitrogen can be correlated with the initial nitrate content of the soil. A preliminary examination of the results indicates that some such minor relationship may exist but further work will be necessary before it can be definitely established and it can, of course, only act within the limits imposed by the factors determining the level of yield, *i.e.* if, for example, the physico-chemical properties of a soil are sufficiently unfavourable the nitrate content may be low and yet be adequate or more than adequate for the needs of the crop.

Comparison of Cotton with Maize.

An absolute contrast to the reaction of cotton to manuring is offered by the results of a similar series of experiments carried out with the maize variety American Early in 1932 and 1933 at seventeen localities. These are illustrated in Fig. 10 obtained by plotting the maximum increases from manuring against the control plot yields in ardebs per feddan in twenty-nine experiments. The diagram gives evidence of a distinct tendency for maize grown on low yielding land to give the greatest response to nitrogen although it must be noted that a group of the experiments tend to depart from this general trend. Disregarding this latter aspect for the moment (it is discussed below) high control plot yield is found to be negatively and significantly correlated with response to nitrogen to the extent of $r = -0{\cdot}56 \pm 0{\cdot}19$; with cotton it will be recalled that, in the season of good response to manuring of 1933, high level of yield was positively correlated with high increase from manuring to almost exactly the same extent. Contrary to cotton there tends therefore to be for maize a maximum yield for the country as a whole towards which the crop may be pushed on any soil by adequate manuring. Moreover the extent of the effect with maize is very much greater than with cotton. In the above twenty-nine experiments the mean yield of the control plots was 7·9 ardebs per feddan and the mean maximum increase 5·6 ardebs or about 70 per cent, while the mean yield of the control plots in the cotton experiments in 1933 (a very exceptional year) was 5·10 kantars per feddan with a mean maximum increase of 1·53 kantars or 30 per cent.

These maize experiments can be further analysed by grouping separately those in which the preceding crop was berseem and those conducted after wheat. This gives fourteen experiments in each group (in one experiment the previous crop was not recorded) being mainly at different centres for both years. The means of the control plot yields and the mean maximum increases from nitrogen in ardebs per feddan for the two groups are as follows :—

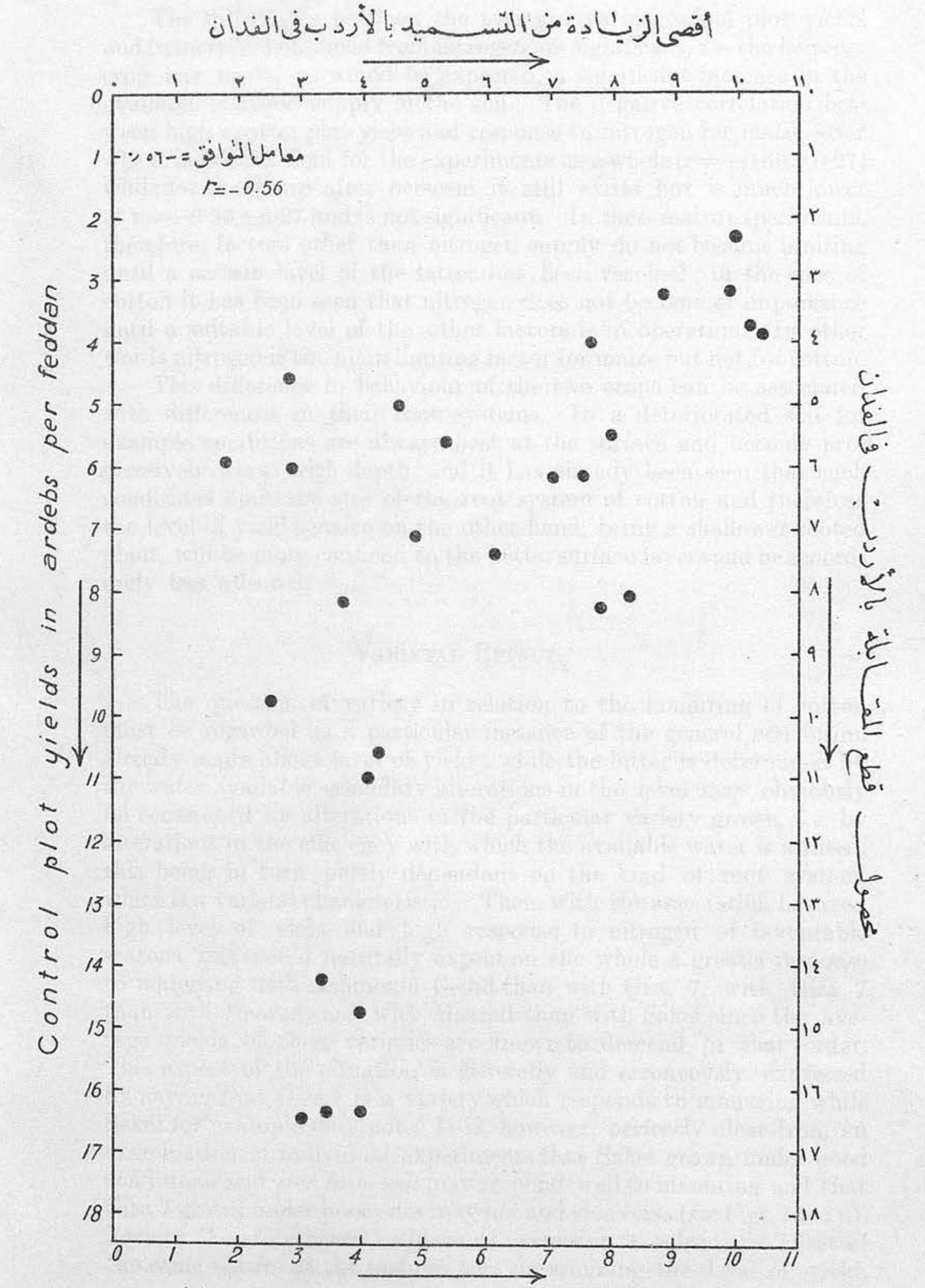
Preceding crop	Mean control plot yields	Mean maximum increases from nitrogen	Totals
Wheat	6.20 ± 0.76	7.00 ± 0.82	13.20
Berseem	9.75 ± 1.24	4.30 ± 0.47	14.05

شكل رقم ١٠

Fig. 10

MAIZE EXPERIMENTS 1932 and 1933
Maximum increases from manuring
Plotted against control plot yields
in Ardebs per feddan

تجارب الذرة لسنتى ١٩٣٢ و ١٩٣٣
اقصى الزيادة من التسميد فى محور
ومحصول قطع المقارنه فى المحور الاخر
بالاردب فى الفدان



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٥/٢٥٣)

The differences between the two groups in control plot yields and in increases obtained from nitrogen are significant, *i.e.* the berseem crop has made, as would be expected, a significant increase in the available nitrogen supply of the soil. The negative correlation between high control plot yield and response to nitrogen for maize after wheat is greater than for the experiments as a whole ($r = -0{\cdot}69 \pm 0{\cdot}27$) while for the group after berseem it still exists but is much lower at $r = -0{\cdot}35 \pm 0{\cdot}27$ and is not significant. In these maize experiments, therefore, factors other than nitrogen supply do not become limiting until a certain level of the latter has been reached ; in the case of cotton it has been seen that nitrogen does not become of importance until a suitable level of the other factors is in operation. In other words nitrogen is the main limiting factor for maize but not for cotton.

This difference in behaviour of the two crops can be associated with differences in their root systems. In a deteriorated soil for example conditions are always best at the surface and become progressively worse with depth, and it has already been seen that such conditions limit the size of the root system of cotton and therefore the level of yield ; maize on the other hand, being a shallower-rooted plant, will be more confined to the better surface layers and be accordingly less affected.

Varietal Effect.

The question of variety in relation to the manuring of cotton must be regarded as a particular instance of the general conclusion already made about level of yield ; while the latter is determined by the water available secondary alterations in the level may obviously be occasioned by alterations in the particular variety grown, *i.e.* by alterations in the efficiency with which the available water is utilised, this being in turn partly dependant on the kind of root system, which is a varietal characteristic. Then, with the association between high level of yield and high response to nitrogen of favourable seasons, one would naturally expect on the whole a greater response to manuring with Ashmouni Gedid than with Giza 7, with Giza 7 than with Maarad, and with Maarad than with Sakel since the average yields of these varieties are known to descend in that order. This aspect of the situation is generally and erroneously expressed by saying that Giza 7 is a variety which responds to manuring while Sakel for example does not. It is, however, perfectly clear from an examination of individual experiments that Sakel grown under good conditions and *free from wilt* may respond well to manuring and that Giza 7 grown under poor ones may not and vice versa (*see* Figs. 5 and 6). Variety therefore takes its place as exercising a subsidiary effect of the same nature as the main factors determining the level of yield.

Before the above conclusions as to the nature of the reaction to manuring can be applied to the country as a whole allowance must be made for the fact, as previously pointed out, that the land on which the experiments were carried out was consistently chosen with a bias toward the better. The average yield obtained in them for any one year is therefore much higher than for the whole country and, with a positive correlation between response to manuring and level of yield, the total effect of 1·53 kantars of 1933 is too high. The bearing of this as well as of the factors determining the nitrogen status of the soil must be taken into consideration before correct conclusions can be drawn as to the exact position of manures in the production of cotton in Egypt. Before going on to do so the nature of the seasonal effect will be discussed.

Seasonal Factors.

Since the effect of manuring mainly depends on the preservation and ripening of the late-formed bolls the important thing as regards the season must be the weather conditions in July, August and September. Fig. 11 shows the mean daily maximum and mean of day temperatures and the mean of day pressure in millibars at the meteorological station at Giza for these months in the three years under discussion. The curves for other stations as far South as Qena show exactly similar trends so that all of the cotton in Egypt can be regarded as growing under the same climatic influences. The mean maximum and mean daily temperatures naturally increase gradually as one moves south but the variations in the curves are replicated at each station.

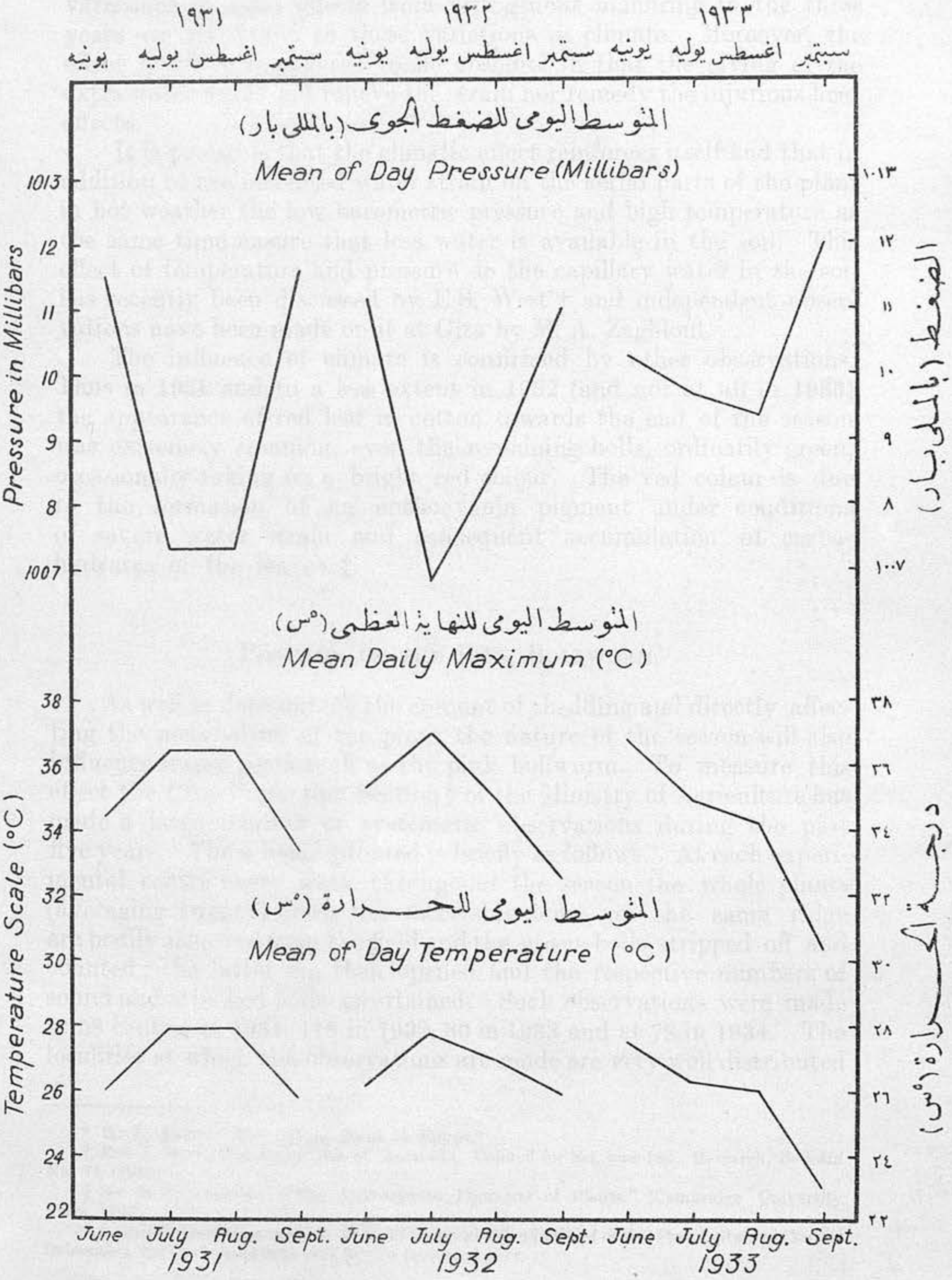
The records show persistently higher temperatures for the months of July, August and September in 1931 than in the other two years; in 1932 the temperature was as high in July but was thereafter much lower while in 1933 the temperature was consistently lower in these three months than in either of the other two years. As against this the 1933 June temperature was abnormally high. Variations in temperature are inversely correlated with variations in barometric pressure and low barometric pressures were accordingly a feature of the hot months of June 1933, July 1932 and of July and August of 1931.

In 1931 and 1932 the nitrogen treated plants with their enlarged vegetative growth passed from relatively cool and suitable months of June into periods of abnormal heat which continued for three months in 1931 and for one month only in 1932; in 1933 on the other hand after the hot weather of June they passed into a period of continuously falling temperature eminently suitable for the maturation of the late-formed bolls. Since it is known that prolonged exposure of the cotton

Fig. 11 شكل رقم ١١

METEOROLOGICAL DATA الأرصاد الجوية

(GIZA STATION) محطة الجيزة



مصلحة المساحة المصرية ١٩٣٥ (٣٥/٢٥٣)

plant in Egypt to temperatures higher than 35° C. * causes severe water strain and heat injury resulting in abnormal shedding, the variations in yield effects from nitrogenous manuring in the three years are attributed to these variations in climate. Moreover, the effect must be considered to be absolute in that the giving of the extra water would not relieve the strain nor remedy the injurious heat effects.

It is probable that the climatic effect reinforces itself and that in addition to the increased water strain on the aerial parts of the plant in hot weather the low barometric pressure and high temperature at the same time ensure that less water is available in the soil. This effect of temperature and pressure on the capillary water in the soil has recently been discussed by E.S. West † and independent observations have been made on it at Giza by M. A. Zaghloul.

The influence of climate is confirmed by other observations. Thus in 1931 and to a less extent in 1932 (and not at all in 1933) the appearance of red leaf in cotton towards the end of the season was extremely common, even the remaining bolls, ordinarily green, occasionally taking on a bright red colour. The red colour is due to the formation of an anthocyanin pigment under conditions of severe water strain and consequent accumulation of carbohydrates in the leaves. ‡

Position of the Pink Bollworm.

As well as determining the amount of shedding and directly affecting the metabolism of the plant the nature of the season will also influence insect pests such as the pink bollworm. To measure this effect the Crop Protection Section § of the Ministry of Agriculture has made a large number of systematic observations during the past five years. The scheme adopted is briefly as follows. At each experimental centre every week throughout the season the whole plants (averaging twenty) from ten successive holes on the same ridge are bodily removed from the field and the green bolls stripped off and counted ; the latter are then opened and the respective numbers of sound and attacked bolls ascertained. Such observations were made at 58 centres in 1931, 118 in 1932, 80 in 1933 and at 78 in 1934. The localities at which the observations are made are very well distributed

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* W. L. Balls : " The Cotton Plant in Egypt."

† Eric S. West : Commonwealth of Australia, Council for Sci. and Ind., Research, Bulletin No. 74 (1932).

§ See M.W. Onslow : " The Anthocyanin Pigments of Plants." (Cambridge University Press, 1925).

‡ Acknowledgement is made to Foad El Gammal Effendi, Chief of the Pink Bollworm Control Subsection, for the information and figures presented here.

throughout the country, are as far as possible the same for each year and frequently coincide with the centres at which the manurial experiments were carried out. The average number of green bolls per twenty plants per season and the respective numbers of sound and attacked are given below :—

Year	Total green bolls (per twenty plants)	Sound bolls (per twenty plants)	Attacked bolls (per twenty plants)
1931...	134.2	94.8	39.4
1932...	139.1	105.6	33.5
1933...	160.0	128.1	21.9
1934...	154.4	114.3	40.1

The number of bolls on the plants was greatest in 1933 and lowest in 1931 which fits in with the expected effect on shedding of the higher temperatures of the latter year. Discrepancies between the years are still further increased by variations in the numbers of bolls per plant attacked by the pink bollworm, these numbers being greatest in 1931 and 1934 and least in 1933. That is to say that in years in which the months of July or August or both are abnormally hot there are not only fewer bolls per plant as a result of the increased shedding but the possibilities are still further reduced by the greater number of bolls attacked by the bollworm.* The resulting seasonal variations shown by the figures for the number of sound bolls correspond excellently with the seasonal variations in yield effects from nitrogen demonstrated from the manurial experiments. The further interpretation of these figures is complicated by the fact that the crop was very early in 1931 and 1934 when the bollworm attack was heaviest and exceptionally late in 1933 when it was lightest ; this opens up the interesting question as to whether the heavier bollworm attack of hot years is a direct climatic effect on the life-cycle of the insect or the consequence of the earlier crop, a question which cannot be discussed here. It may also be recalled that in the spacing and manuring experiments the trend of the results for 1931, the hottest season, was in favour of the closest spacing irrespective of manuring, i.e. an early crop was particularly desirable in that year.

* The combined effect of shedding and bollworm attack may be absolutely disastrous in individual cases.

Irrigation Water taken from the River by All Egypt.

(in millions of cubic metres)*

Month	Year		
	1931	1932	1933
February... ...	1,896	2,051	2,610
March	1,935	2,048	2,557
April	1,641	1,678	1,969
May	1,580	1,726	2,147
June	1,698	2,215	2,514
July	2,390	2,664	2,854
Total ...	11,140	12,382	14,651

To the end of June the available water was least in 1931 and greatest in 1933, the suggestion offered by the figures being that watering rotations may have been hard on cotton in 1931 and 1932 in the early part of the season. It is now clear from the analysis of the situation that any such shortage would indirectly affect response to nitrogen by lowering the level of yield. It is impossible to offer any accurate estimate (beyond the evidence of the watering experiments) as to whether or to what extent this factor has operated in the manurial experiments and the question must be left in the region of suggestion. The above figures for available water should be adjusted, for example, for the area under rice respectively in the three years.

The Nitrogen Status of the Soil.

Below are given the figures for total nitrogen and organic carbon obtained on a profile taken from fertile perennially irrigated land.

Depth of layer in cms	% Total nitrogen (N)	% Organic carbon (C)	Ratio : $\frac{\text{Carbon}}{\text{Nitrogen}}$
0–20	0.096	1.03	10.7
20–45	0.076	0.79	10.4
45–70	0.048	0.61	12.7
70–95	0.050	0.55	11.0

* Figures of the Ministry of Public Works.

The amounts of total nitrogen and organic carbon are small even in the surface layers but the figures bring out a distinctive feature of Egyptian soils in that the rates of decrease in these amounts with depth is very gradual and is usually in normal * soils associated with a slight but progressive increase in the carbon to nitrogen ratio. The practical question which immediately arises from a consideration of such profiles is the extent to which, if any, the subsoil organic matter contributes to the nitrate supplying power of the soil. Experiments are being carried out on this point but in the meantime the only information available is the initial nitrate content of the layers of profiles taken at sowing time in connection with manurial experiments carried out on cotton this year (1934). The figures obtained on one such profile from Mallawi in Upper Egypt are :—

Depth of layer in cms	Nitrate Nitrogen in parts per million of air dry soil
0—25	17.5
25—50	12.5
50—75	4.5
75—100	11.5
	TOTAL ... 46.0
	Average ... 11.5

This average of 11·5 parts per million corresponds roughly to 50 kilos of nitrogen per feddan of metre depth of which the major portion is found in the subsoil. The results for eight such profiles range from a total of 31 kilos per feddan up to 54 kilos and give an average of 44 kilos. The importance of this aspect of the question is that if the subsoil organic matter directly contributes in any substantial degree to the nitrate supply then alterations (apart from cases of soil deterioration) in the general nitrogen status of soils in Egypt must be slow. Considering that the general rotation practiced is the same to-day as twenty years ago, there may be no greater need for nitrogenous fertilisers for cotton now than then; except, of course, such as may have been created by the quicker development necessitated by the shorter growing season.

The nitrogen status of the soil after berseem and after wheat has already been shown to influence considerably the response to nitrogen fertilisers of maize grown after these crops. Similar data for cotton are not sufficiently extensive to permit in its case of generalisation. In the maize experiments, however, the amounts of nitrogen made

* Soil deterioration may be associated with marked reduction in the soil organic matter.

available from the berseem are at the same time clearly insufficient to mask more fundamental differences in the nitrogen status of the soil at the various centres. This same feature is also evident in the two "Sharaqui" experiments dealt with below; they were carried out on different parts of the same farm, both after beseem, and it is again evident that the additional nitrogen provided by the latter has failed to offset the more permanent differences between the two parts of the farm.

"Sharaqui" Experiments.

A further factor which may affect the nitrogen status of the soil is illustrated by two experiments carried out on a farm on basin land after berseem near Qous in Upper Egypt in the years 1932 and 1934. The usual custom there is to give a light watering before ploughing in order to soften the land and the aim of the experiments was to estimate the effect of this watering on the available nitrogen. The layout took the form of six blocks, three of which were watered before ploughing and three ploughed dry. Each block contained sixteen plots 1/40th of a feddan in area arranged in the form of a Latin square to which nitrate was applied at thinning at the rate of 0, 1, 2 and 3 sacks per feddan, there being therefore twenty-four observations for each level of nitrogen, twelve on land ploughed dry and twelve on land ploughed after a watering. The results are averaged below. (There was about a month's interval between the ploughing—watering and the sowing of the crop.)

Treatments	Watered before ploughing		Ploughed dry	
	Yield in kantars per feddan	Percentage of crop at 2nd picking	Yield in kantars per feddan	Percentage of crop at 2nd picking
1932 Experiment. *Variety: Giza 7*				
No manure...	6.98	22.9	7.39	27.9
1 N	7.38	26.7	7.39	31.4
2 N	7.48	31.1	6.73	36.5
3 N	7.03	34.1	6.96	39.1
1934 Experiment. *Variety: Giza 3*				
No manure...	4.85	5.8	5.29	7.3
1 N	5.99	5.6	6.64	8.5
2 N	6.73	6.6	7.18	9.5
3 N	7.31	6.8	7.96	11.9

While the level of nitrogen of the land on which the 1932 experiment was carried out is so high that positive effects of the treatments on yield are small, the results show very consistent trends. On the land watered before ploughing the application of one sack of nitrate increased the yield and depression does not occur until the third sack is reached. The cotton on the land ploughed dry on the other hand gave the maximum yield without any application of nitrogen while depression was caused by the second sack. The difference in reaction is confirmed at all levels of nitrogen by the continuously higher proportion of the crop obtained at the second picking on the land ploughed dry. The reduction in the nitrogen level occasioned by watering the land before ploughing in this experiment is therefore equivalent to roughly rather more than 100 kilos of nitrogenous fertiliser per feddan (*see* Fig. 12).

The 1934 experiment was carried out on land the nitrogen level of which is known to be much lower. Both on the watered and unwatered land the effects of the nitrogen applications are correspondingly greater but again the consistent differences in the two sets of figures confirm the fact that a pre-ploughing watering reduces the available soil nitrogen, although not quite to the same extent as on richer land.

These "Sharaqui" experiments were, of course, only possible because a tractor was available and a reasonable tilth could be obtained on the dry-ploughed land. From an economic point of view the question obviously comes down to whether the extra cost of ploughing dry can be offset against the loss of available nitrogen which ploughing wet is bound to entail.

Effect of Phosphate.*

When dealing with the measurement of the nature of the effect of manuring an experiment at Gimmeiza was quoted where the highest dose of nitrogen (three sacks of nitrate) was without influence on yield, as compared with two sacks, until it was accompanied by a dressing of superphosphate, the latter itself, apart from this, being without significant effect in the experiment either when given alone

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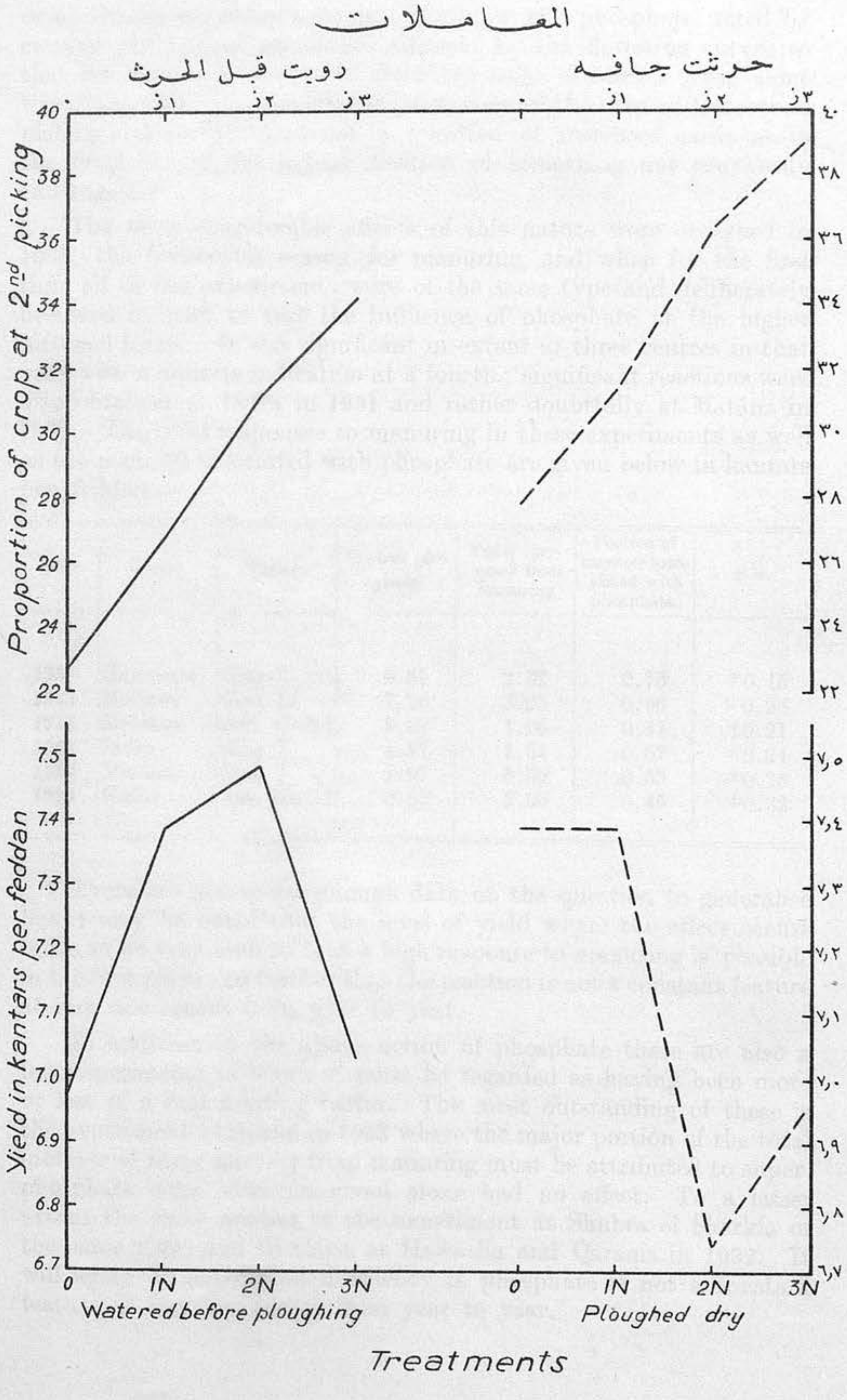
* The following discussion refers only to water soluble phosphate. It has been conclusively shown from numerous experiments that, in the cases where phosphate exerts an effect, it can only do so if applied in a water-soluble form, insoluble phosphates such as finely ground mineral phosphates have little or no effect. This statement applies to other Egyptian crops as well as cotton. Further, the idea that gypsum is the effective agent in superphosphate is incorrect. In the experiments the superphosphate dressing is fassed in on the south side of the ridge before sowing.

Fig. 12

شكل رقم ١٢

SHARAQI EXPERIMENT 1932 تجربة الشراقى سنة ١٩٣٢



مصلحة المساحة المصرية سنة ١٩٣٥ (٣٥/٢٥٣)

or at the lower nitrogen levels. Moreover the phosphate acted by causing the highest maximum attained by the flowering curves so that the increased yield over the three sacks of nitrate given alone was obtained with an unaltered proportion of the crop at the second picking; it is therefore not a question of increased earliness in the crop but of the actual creation of something not previously existing.

The most considerable effects of this nature were observed in 1933, the favourable season for manuring, and when for the first time all of the experiments were of the same type and deliberately designed in part to test the influence of phosphate at the higher nitrogen levels. It was significant in extent at three centres in that year with a definite indication at a fourth; significant reactions were also obtained at Defra in 1931 and rather doubtfully at Matâna in 1932. The total responses to manuring in these experiments as well as the portions associated with phosphate are given below in kantars per feddan:—

Year	Centre	Variety	Control plot yields	Total increases from manuring	Portion of increase associated with phosphate	S.E.
1933	Gimmeiza	Giza 7	5.27	2.32	0.75	±0.15
1933	Mallawi ...	Giza 19	7.26	3.23	0.96	±0.28
1933	Matania ...	Ash. Gedid	9.02	4.06	0.47	±0.21
1931	Defra ...	Giza 7	4.97	1.51	0.67	±0.24
1932	Matâna ...	Giza 7	1.97	5.50	0.55	±0.28
1933	Kufur ...	Ash. Gedid	5.63	3.00	0.45	±0.32

There are not so far enough data on the question to generalise but it may be noted that the level of yield where the effect occurs tends to be very high so that a high response to manuring is possible in the first place and further that the reaction is not a constant feature at any one centre from year to year.

In addition to the above action of phosphate there are also a few experiments in which it must be regarded as having been more or less of a real limiting factor. The most outstanding of these is the experiment at Sakha in 1933 where the major portion of the total increase of three kantars from manuring must be attributed to superphosphate since nitrogen given alone had no effect. To a lesser extent the same applies to the experiment at Shubra el Sharkia of the same year, and to those at Hawaslia and Qaraqis in 1932. It will again be noted that deficiency in phosphate is not a constant feature at any one centre from year to year.

From their possible importance in individual cases the factors deciding the necessity for the use of superphosphate obviously require further investigation but in the meantime from the point of view of the experiments as a whole its position in the manuring of cotton may be regarded as negligible. Of the more than ninety experiments on which this report is based only in the ten discussed above are there real yield effects from phosphate so that, even with the inclusion of further experiments showing minor and insignificant increases the average effect is small. In dealing with the experiments as a whole the results of the individual experiment were first of all averaged for the different nitrogen levels so that a substantial part of the phosphate effect has been included in the mean result for manuring in any one year.

Effect of Potash.

An extensive series of qualitative experiments with sulphate of potash was begun in 1933 and is being continued. Numerous experiments with potash have, of course, been carried out in the past with an invariably negative or dubiously positive result but it is considered that the reaction to it is perhaps worth further study. The type of experiment adopted was a five-sided Latin square and the treatments, after the control, 150 kilos of nitrate alone and in combination with superphosphate and sulphate of potash both separately and together. The potash manure was given at the rate of 150 kilos per feddan and the superphosphate at the rate of 200 kilos, both being applied before sowing. The results are given in Table 15 of the appendix. Of the twenty-three experiments of 1933 six show a significant reaction to potash, there being in three of them marked depressions, and in the other three slight increases, in yield. The average effects as compared respectively with the plots receiving nitrogen alone and those receiving nitrogen and superphosphate, on the corresponding potash plots are given below in kantars per feddan for these six experiments :—

Centre	Control plot yield	Average increase or decrease from potash	S.E.
Kufur el Raml	8.13	—0.83	±0.19
Bassandila	6.27	—0.88	±0.18
Shubra Sindi	6.27	—0.66	±0.18
Manshia	4.70	+0.53	±0.18
Tala	3.07	+0.29	±0.07
El Sad	3.66	+0.29	±0.07

The depressing effects at the first three centres are much greater than the increases obtained at the second three. Since at all of the twenty-three localities at which the potash experiment was carried out the main nitrogen and phosphate experiment was also conducted it may be concluded that, for 1933 at least, potash was even more negligible than phosphate as regards positive effect on cotton for the country as a whole. On the contrary the considerable depressions in yield occasioned by its use at three of the *high-yielding* centres afford the interesting suggestion that the potash level in fertile Egyptian soils may even be too high for cotton, *i.e.* a natural excess of available soil potash may in some cases be a limiting factor. As against this it should also be noted that, at the centres showing positive responses the initial level of yield is much lower. Depressions in yield have also been obtained with superphosphate but they have never, so far, been significant in amount.

Effect of Phosphate and Potash on Quality.

Faced with the fact that potash and phosphatic manures have, on the whole, negligible or even depressing effects on the yield of cotton the individuals who consider the use of these manures essential fall back on a supposedly good effect on quality in order to justify expenditure on them; what evidence there is is all against this assumption.

Economic Aspect.

The economic side of the question can be dealt with here only from the point of view of the country as a whole; the possibilities in the individual case are determined by the relative intensity of the factors which have been discussed.

The total mean increases over the control plot yields at three successive levels of nitrogen for the experiments for the three years are again set out below together with the mean control plot yields, all in kantars per feddan.

Year	Mean control plot yield	Total mean increases at		
		IN	2N	3N
1931	4.62	0.53	0.74	0.86
1932	4.76	0.71	1.08	1.39
1933	5.10	0.75	1.18	1.53

The actual successive increments of yield associated with each sack of nitrate and their monetary value (taking a kantar of cotton as being worth L.E. 3) are :—

Year	IN	Value	2N	Value	3N	Value
		L.E.		L.E.		L.E.
1931...	0.53	1.59	0.21	0.63	0.12	0.36
1932...	0.71	2.13	0.37	1.11	0.31	0.93
1933...	0.73	2.25	0.43	1.29	0.35	1.05

If the cost of a sack of nitrate be taken as L.E. 0·70 then, so far as the experiments go, the first sack only was profitable in 1931 but both in 1932 and 1933 the third still left a small profit. From the seasonal point of view the only really permanent part of the nitrate effect comes of course from the first sack; to apply more is a pure speculation on what the weather conditions are going to be in July and August. This speculation, as is well known, brought in a very handsome return for example on high-yielding land in Upper Egypt in 1933 but in 1931 when the weather in these months was very unfavourable (high temperatures) it did not. In fact it is apparent that in suitable seasons on high-yielding land nitrate up to four and even five sacks per feddan would be an excellent proposition.

The land on which the experiments were carried out is much higher yielding than the average so that the above figures should be considerably adjusted downwards when considering the country as a whole. If it had been possible to select sites for the experiments so as to include some of the really poor soils it is probable that one would have reached the opposite extreme of good land and might have been able to record consistent depressions from added nitrogen –the level of yield would then have been so low that the available nitrogen in the soil is more than sufficient to meet the requirements of the plant. The main feature, however, of experiments carried out on poor soils is that the variation due to error is so large that the treatment effect is not statistically significant and there is in fact no point in doing the experiments at all.

Practical Applications.

From the practical point of view the sole aim in carrying out an extensive series of field experiments such as those on which this report is based is to arrive at a proper basis for advisory work, *i.e.* to be able to give a reasonably accurate answer to the question of how much fertiliser to apply to cotton when grown on any individual piece of land (assuming, of course, that the factors of sowing-date, spacing and watering are optimal). It is now established that a correct answer to the question involves a foreknowledge of the kind of season (which is clearly impossible) of the probable yield level (*i.e.* the physico-chemical properties of the soil) and entails some estimate of the nutrient-supplying power of the soil. The only one of these susceptible of measurement by reasonably rapid methods, in view of the number of samples which would be involved, is nutrient-supplying power. It has already been mentioned that, with really fertile soils, a partial correlation may exist between initial nitrate content and response to manuring but taking the range of the soils as a whole it would be impossible to interpret figures for nutrient content in the absence of some estimate of physical properties. And the measurement of the physico-chemical properties of soils, even were it known what actual measurements to make, is too lengthy and tedious a process for practical use on a large scale.

With maize the case is quite different since it has been seen that there tends to be a maximum yield for the whole country towards which the crop can be pushed on any soil by adequate nitrogenous manuring. In the case of maize, therefore, an estimate of the nitrogen status of the soil alone would provide some indication of the amount of fertiliser to apply since the crop is not affected to the same extent by subsoil conditions.

SUMMARY.

Owing to the pink bollworm cotton growing in Egypt is dominated by the necessity for an early crop ; as early a rise and as high a maximum of the flowering curve as are possible are imperative since there must always be much more than an element of uncertainty about the fate of the late-formed bolls. This feature of the situation is measured in the experiments by the figures for the proportion of the total yield obtained at the second picking—only where an increase in yield from an application of a factor is accompanied by an unchanged or reduced percentage at the second picking is that factor regarded as having been really limiting.

The factors of *sowing-date, spacing and watering* are limiting ones in this sense since their proper adjustment is determined by the necessity for the early crop.

Mean deficiency in soil nitrogen is limiting in the experiments only to the extent of the half-kantar obtained in 1931 with one sack

of nitrate and without alteration in the proportion of the crop at the second picking. This figure includes the few exceptional experiments in which nitrogen deficiency was extreme.

Yield effects from nitrogen are thereafter entirely and positively correlated with (1) high level of yield and (2) increased proportion of the crop at the second picking, *i.e.* on the ripening of the late-formed bolls.

Whether these two correlations operate or not depends on the weather conditions in July and August. When these months are excessively hot as in 1931 shedding was so excessive that there was no economic return after the first sack; when they are cool more bolls come to maturity. There are also definite indications that the greater amount of shedding in hot seasons is reinforced by a heavier pink bollworm attack, *i.e.* by an actual larger number of attacked bolls per plant, the total number of bolls having already been reduced by shedding.

The *level of yield* which primarily conditions the amount of response possible and so dominates the situation is an expression of the degree of water strain to which the plants have been subjected. The amount of water available is directly related to the size of the root system and the latter is in turn decided by the physical properties of the soil such as permeability to water and air, properties which are in the main a reflection of the amount of deterioration the soil has undergone. Large results from nitrogenous manuring can only be obtained on first-class land in suitable seasons.

The *variety* grown may cause subsidiary alterations in the level of yield through variations in the efficiency with which the available water is utilised.

Finally it has been shown that, in contrast to cotton, nitrogen is the main factor limiting the yield of the shallower-rooted maize crop.

CONCLUSIONS.

The main, if not the only, practical steps which can be taken (assuming average seasons and the permanence of the pink bollworm) to increase the possibilities of nitrogenous manuring of cotton in Egypt must obviously be directed to raising the general yield level. This can only be accomplished by the prevention and remedying of soil deterioration * by the general adoption of intensive drainage.

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* *See* "The Nature of Soil Deterioration in Egypt." Technical Bulletin No. 148 of the Ministry of Agriculture (1934).

APPENDIX

In the following tables the experiments marked with an asterisk(*) are those in which the treatments have not exerted a statistically significant effect as judged by the Z test. The level of probability taken for significance throughout is 20 :1 ($P=0{\cdot}05$). No conclusions, therefore, can be drawn from the experiments marked with an asterisk except that the treatment effect is not significant; in the case of the others differences greater than three times the standard error (S.E.) can be regarded as real.

Throughout the tables IN means a dressing of any artificial nitrogenous fertiliser supplying nitrogen at the rate of 15½ kilos per feddan, etc. — see foot-note 2, page 4.

N.B.—The equivalents of the Egyptian weights and measures used in the British and metric systems are :—

1 Feddan=1.038 acres=2,400 square metres.

1 Kassaba=3.88 yards=3.55 metres.

1 Kantar of seed cotton=315 rotls.

1 rotl=0.99 lbs=449 grammes.

1 Ardeb of maize=308·6 lbs=140 kilos.

TABLE 1.—WATERING EXPERIMENTS.

1ST WATERING AFTER 21 DAYS AND 30 DAYS IN COMBINATION WITH 12, 15 AND 18 DAY WATERING INTERVALS.

Layout: SEVEN-SIDED LATIN SQUARE. *Plot size:* 1/20th FEDDAN.

Locality	Previous crop	Dates of sowing and picking	Variety	TREATMENTS: 1st watering after 21 days: 12	15	18	1st watering after 30 days: 12	15	18	Normal practice of district	S.E.	Yields
*Gimmeiza ...	Maize ...	16- 3-31 4- 9-31 18-10-31	Giza 7 ...	3.05 30.8	3.20 33.3	2.92 34.0	3.31 37.4	3.17 39.4	3.19 35.8	3.08 41.2	— —	In kantars per feddan. Proportion at 2nd pick.
*Bassandila ...	Berseem.	23- 3-31 17- 9-31 8-10-31	Sakel ...	5.64 12.0	6.26 8.7	5.76 9.5	6.09 11.2	5.93 12.2	5.82 8.2	5.80 8.2	— —	In kantars per feddan. Proportion at 2nd pick.
Abu Raqaba ...	Maize ...	20- 3-31 26- 8-31 29- 9-31	Giza 7	5.18 25.2	4.49 22.6	4.56 17.5	5.05 27.9	4.85 25.0	4.05 36.2	4.04 25.6	0.19 —	In kantars per feddan. Proportion at 2nd pick.
Gimmeiza ...	Berseem.	2- 3-32 23- 9-32 18-10-32	Giza 7 ...	4.74 21.0	4.36 17.4	4.12 18.4	4.60 20.5	4.79 19.6	4.34 17.9	3.60 24.1	0.11 —	In kantars per feddan. Proportion at 2nd pick.
*Kafr el Sheikh	—	24- 3-32 26- 9-32 17-10-32	Sakha 4 ...	5.20 39.4	5.93 42.8	5.13 38.9	4.73 39.5	4.91 40.6	5.75 37.9	5.11 39.0	— —	In kantars per feddan. Proportion at 2nd pick.
Sakha	Maize ...	10- 3-32 17- 9-32 10-10-32	Sakel ...	5.45 51.8	5.18 43.6	4.83 46.4	4.97 53.6	4.56 51.2	4.63 49.4	4.15 51.0	0.09 —	In kantars per feddan. Proportion at 2nd pick.

*Siberbai ...	Berseem	16- 3-32 17- 9-32 11-10-32	Sakha 4 ...	3.62 36.5	3.51 41.2	3.30 42.3	3.33 38.0	3.46 36.1	3.31 38.2	3.44 32.6	— —	In kantars per feddan. Proportion at 2nd pick.
*Mit Gaber ...	Wheat...	6- 3-32 5- 9-32 12-10-32	Nahda. ...	6.10 11.9	5.81 14.3	6.19 13.4	6.65 12.5	6.44 10.7	6.12 10.4	6.28 15.6	— —	In kantars per feddan. Proportion at 2nd pick.
*Qaha	Maize ...	9- 3-32 6- 9-32 10-10-32	Ashmouni Gedid ...	7.15 8.6	7.06 5.9	7.10 7.7	6.77 8.6	6.52 9.2	6.19 11.7	6.39 9.1	0.43 —	In kantars per feddan. Proportion at 2nd pick.
Gimmeiza ...	—	7- 3-33 — —	Giza 7 ...	7.66 55.3	6.91 53.5	6.51 46.0	7.28 58.2	6.91 58.0	6.48 55.9	5.96 67.2	0.16 —	In kantars per feddan. Proportion at 2nd pick.
*Siberbai ...	Berseem.	21- 3-33 6- 9-33 4-10-33	Ashmouni Gedid ...	3.59 45.0	3.66 51.0	4.00 45.3	3.50 50.3	3.93 47.9	4.09 47.6	4.09 52.1	0.30 —	In kantars per feddan. Proportion at 2nd pick.
Qaha	Maize ...	5- 3-33 3- 9-33 —	Ashmouni Gedid ...	6.47 14.6	6.03 22.4	5.95 17.7	6.36 18.8	5.55 21.9	4.78 22.7	5.15 20.8	0.20 —	In kantars per feddan. Proportion at 2nd pick.
Matâna	Maize ...	15- 3-33 28- 8-33 —	Giza 3 ...	8.18 24.6	8.11 28.6	6.98 24.2	8.69 25.9	7.83 25.2	6.85 32.5	8.34 40.2	0.31 —	In kantars per feddan. Proportion at 2nd pick.
Sids	Fallow...	2- 3-33 12- 9-33 —	Giza 2 ...	6.18 21.7	6.64 11.7	6.47 11.8	6.25 15.5	5.76 20.6	6.04 22.8	4.42 23.8	0.48 —	In kantars per feddan. Proportion at 2nd pick.

TABLE 2.—VARIETY, SPACING AND MANURING EXPERIMENTS 1931.

Layout : NINE RANDOMISED BLOCKS WITH TWELVE PLOTS, 1/40th FEDDAN IN AREA, PER BLOCK. THREE BLOCKS WHOLLY DEVOTED TO EACH SPACING. DISTANCE BETWEEN HOLES 25–30 cms. (Yields in Kantars per Feddan.)

Locality	Previous crop	Dates of sowing and picking	Variety	TREATMENTS 10 Ridges/2 Kassabas 1N	10 Ridges/2 Kassabas 2N	11 Ridges/2 Kassabas 1N	11 Ridges/2 Kassabas 2N	12 Ridges/2 Kassabas 1N	12 Ridges/2 Kassabas 2N
LOWER EGYPT									
Gimmeiza	—	—	Sakel	4.75	4.48	4.71	4.86	4.91	4.56
			Giza 7... ...	6.65	7.04	6.97	7.17	6.59	7.16
			Maarad ...	6.40	6.60	6.67	6.53	6.42	6.53
Siberbai	Berseem ...	12- 3-31	Sakel	2.45	2.70	2.50	2.61	2.65	2.47
		17- 9-31	Giza 7... ...	4.22	4.73	4.71	4.90	4.55	4.83
		8-10-31	Maarad ...	4.20	4.53	4.39	4.42	4.39	4.67
Talkha	Berseem ...	21- 3-31	Sakel	5.24	5.51	5.03	5.08	5.23	5.35
		30- 9-31	Giza 7 ...	6.55	7.39	6.86	7.03	5.99	6.63
		13-10-31	Maarad ...	6.51	6.94	5.99	6.52	6.03	6.12
Zebeida	Beans ...	18- 2-31	Sakel	4.14	4.57	4.64	4.86	4.68	4.73
		31- 8-31	Giza 7... ...	6.45	6.61	7.10	6.76	7.31	8.01
		5- 9-31	Maarad ...	6.02	5.74	6.56	6.02	5.55	6.59
Shubra el Sharkia	Rice ...	6- 4-31	Sakel	2.69	2.80	2.92	2.74	2.88	2.99
		29- 9-31	Giza 7 ...	3.51	3.97	3.85	4.07	3.76	3.83
		9-11-31	Maarad ...	2.88	3.05	3.13	3.26	2.91	3.36
Qaha	Maize ...	13- 3-31	Ashmouni Gedid	3.12	3.99	3.84	3.70	3.93	4.49
		30- 8-31	Giza 7 ...	3.33	4.42	3.47	4.28	3.90	4.30
		3-10-31	Maarad ...	3.47	3.56	3.18	3.67	3.80	3·95

Abu Raqaba	Maize ...	10– 3–31	Ashmouni Gedid	6.24	6.42	6.40	6.72	6.90	7.59
		24– 8–31	Giza 7 ...	5.64	5.64	5.79	5.62	6.03	6.07
		13–10–31	Maarad ...	4.76	4.50	4.54	4.60	4.65	4.77
Mit Gaber	Berseem ...	5– 3–31	Ashmouni Gedid	6.70	6.72	6.42	6.97	6.51	7.08
		15– 9–31	Giza 7 ...	6.30	6.49	5.96	6.34	5.95	6.69
		7–10–31	Maarad ...	5.77	6.02	5.55	6.17	5.87	6.31
UPPER EGYPT				$1\frac{1}{2}$ N	3 N	$1\frac{1}{2}$ N	3 N	$1\frac{1}{2}$ N	3 N
Helwan	Tomatoes	8 – 3–31	Ashmouni Gedid	5.22	5.29	4.04	4.38	5.21	5.85
		10– 9–31	Giza 7 ...	3.49	4.22	3.21	2.55	3.81	3.68
		12–10–31	Giza 3 ...	4.81	4.63	3.32	4.02	4.98	4.33
Kufur	Berseem ...	12– 3–31	Ashmouni Gedid	5.08	5.06	5.04	5.38	4.89	4.65
		23– 8–31	Giza 7 ...	4.44	4.44	4.02	3.81	3.94	3.79
		7–10–31	Giza 3 ...	5.03	5.10	5.53	5.52	5.10	5.23
Hawaslia	—	—	Ashmouni Gedid	4.78	6.05	4.83	5.23	4.53	5.44
		—	Giza 7 ...	4.49	5.29	4.13	4.91	4.53	4.95
		—	Giza 3... ...	4.47	5.42	4.87	5.53	4.57	5.48

TABLE 3.—VARIETY, SPACING AND MANURING EXPERIMENTS 1932.

(Yields in Kantars per Feddan, layout as in Table 2)

Locality	Previous crop	Dates of sowing and picking	Variety	10 Ridges/2 Kassabas IN	10 Ridges/2 Kassabas 2N	11 Ridges/2 Kassabas IN	11 Ridges/2 Kassabas 2N	12 Ridges/2 Kassabas IN	12 Ridges/2 Kassabas 2N
LOWER EGYPT.									
Gimmeiza	Berseem ...	29- 2-32	Sakel	2.85	2.94	3.41	3.51	3.08	2.59
		28- 8-32	Giza 7 ...	6.88	6.94	7.05	7.44	7.12	6.78
		14-10-32	Maarad ...	6.27	6.69	6.56	6.98	6.54	6.38
Siberbai	Maize ...	16- 3-32	Sakel	2.96	2.68	2.60	3.30	2.45	2.85
		17- 9-32	Giza 7 ...	5.41	5.71	5.69	6.05	5.33	5.56
		12-10-32	Maarad ...	4.74	5.71	5.10	5.67	5.22	5.46
Sakha	Maize ...	20- 3-32	Sakel	5.58	5.96	5.90	6.64	6.24	6.58
		13- 9-32	Giza 7 ...	6.85	7.74	7.93	8.19	7·61	8.44
		7-10-32	Maarad ...	6.24	7.06	7.06	8.02	7.19	8.08
Kafr el Sheikh	Berseem ...	24- 3-32	Sakel	6.46	4.48	4.16	4.76	4.61	5.16
		25- 9-32	Giza 7 ..	6.39	6.64	6.64	7.04	6.51	6.34
		18-10-32	Maarad ...	6.39	6.45	6.09	6.34	6.17	6.43
Defra	Maize ...	15- 3-32	Sakel	3.46	3.49	3.44	3.64	3.45	3.38
		9- 9-32	Giza 7... ...	5.23	5.65	5.19	5.76	5.18	5.56
		8-10-32	Maarad ...	5.12	5.71	5.14	5.82	5.23	5.96
Qaraqis	Berseem ...	20- 3-32	Sakel	4.11	4.14	4.02	4.20	3.72	3.61
		18- 9-32	Giza 7 ...	7.82	8.14	8.30	8.59	7.93	8.06
		11-10-32	Maarad ...	6.88	6.92	7.09	7.45	6.92	6.76

Motamadiya	Berseem ...	11- 3-32	Sakel	3.19	3.21	3.21	4.19	2.81	2.68
		22- 9-32	Giza 7 ...	6.66	7.23	6.91	7.95	7.66	8.21
		22-10-32	Maarad ...	6.81	7.55	6.79	8.25	6.96	7.74
Qaha	Maize ...	16- 3-32	Ashmouni Gedid	5.96	6.29	6.46	5.47	6.03	6.79
		13- 9-32	Giza 7 ...	6.82	7.38	6.72	7.32	6.88	7.60
		10-10-32	Maarad ...	5.52	5.54	5.85	5.81	5.86	6.20
Halawat	Maize ...	14- 3-32	Ashmouni Gedid	6.89	7.88	7.24	8.01	7.21	8.87
		15- 9-32	Giza 7 ...	7.10	8.12	7.56	8.03	8.13	8.24
		6-10-32	Maarad ...	6.76	7.46	7.24	7.63	7.43	7.60
UPPER EGYPT				1 ½ N	3 N	1 ½ N	3 N	1 ½ N	3 N
Matania	Maize ...	5- 3-32	Ashmouni Gedid	9.82	9.96	9.32	9.52	9.92	10.11
		10- 9-32	Giza 7 ...	7.87	7.87	8.67	7.91	8.12	7.94
		17-10-32	Giza 3 ...	8.49	7.20	8.10	7.80	9.28	8.81
Kufur	Maize ...	8- 3-32	Ashmouni Gedid	9.12	9.65	9.56	9.94	10·03	9.82
		17- 9-32	Giza 7 ...	8.76	9.01	8.46	8.91	8.19	9.14
		28-10-32	Giza 3 ...	8.52	8.65	8.04	8.69	8.69	8.46
Hawaslia	Maize ...	6- 3-32	Ashmouni Gedid	5.61	5.95	5.27	5.90	4.61	5.37
		3- 9-32	Giza 7 ...	4.95	4.99	4.99	5.31	4.53	4.68
		22- 9-32	Giza 3 ...	4.46	5.42	4.63	5.44	4.08	4.51
Kom Ombo	Beans ...	6- 3-32	Ashmouni Gedid	6.00	5.66	4.56	5.27	4.69	5.10
		25- 8-32	Giza 7 ...	5.93	5.70	5.11	5.92	5.05	5.01
		26- 9-32	Giza 3... ...	5.71	6.66	6.55	6.55	5.87	5.64

TABLE 4.—1931 EXPERIMENTS (LOWER EGYPT). INCREASING AMOUNTS OF NITRATE IN ONE AND IN TWO DOSES. *Layout* : CHEQUER WITH EIGHT REPLICATIONS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS								Mean	S.E.	Yields
				No manure	1N	One dose			Two doses					
						1·5 N	2N	2·5 N	1·5 N	2N	2·5 N			
Qaraqis ...	Giza 7 ...	—	16– 3	5.54	5.83	6.02	5.95	5.95	5.98	5.98	6.16	5.93	0.09	In kantars per fed.
			22– 9	93.4	98.3	101.4	100.4	100.4	100.9	100.9	103.9	100.0	1.45	In per cent.
			16–10	6.6	6.3	6.9	6.9	7.7	7.2	6.4	6.2	—	—	Proportion at 2nd pick.
Defra ...	Giza 7 ...	—	9– 3	3.64	4.48	4.73	4.64	4.75	4.46	4.51	4.54	4.47	0.12	In kantars per fed.
			10– 9	81.3	100.2	105.6	103.7	106.2	99.8	100.9	101.6	100.0	2.74	In per cent.
			14–10	7.9	8.5	8.1	9.3	9.4	7.8	8.8	7.7	—	—	Proportion at 2nd pick.
Mit Gaber ...	Maarad ...	—	4– 3	4.32	4.59	5.10	4.79	4.64	4.87	4.84	4.60	4.73	0.05	In kantars per fed.
			11– 9	91.3	97.0	107.7	101.3	98.6	103.0	102.4	97.3	100.0	1.07	In per cent.
			7–10	30.5	30.1	29.6	32.1	36.0	30.0	31.8	30.0	—	—	Proportion at 2nd pick.

TABLE 5.—1931 EXPERIMENTS (UPPER EGYPT). INCREASING AMOUNTS OF NITRATE IN ONE AND IN TWO DOSES. *Layout*: CHEQUER WITH EIGHT REPLICATIONS. *Plot size*: 1/40th FEDDAN.

Locality	Variety	Dates of sowing and picking	TREATMENTS								Mean	S.E.	Yields
			No manure	IN	One dose			Two doses					
					2N	3N	4N	2N	3N	4N			
*Asyût ...	Ashmouni Gedid ...	19–4	7.62	8.27	8.43	8.89	8.86	8.19	8.25	8.07	8.32	0.43	In kantars per fed.
		2–9	91.6	99.4	101.3	106.8	106.5	98.5	99.2	97.0	100.0	5.21	In per cent.
		19–9	19.6	16.5	20.7	21.1	20.6	20.7	21.0	23.8	—	—	Proportion at 2nd pick.
Hawaslia ...	Giza 7 ...	8–3	4.57	5.64	6.30	6.34	6.73	6.30	6.48	7.22	6.20	0.23	In kantars per fed.
		3–9	73.7	90.9	101.7	102.2	108.6	101.7	104.5	116.5	100.0	3.63	In per cent.
		28–9	8.3	7.9	11.3	12.3	13.2	9.8	11.5	12.3	—	—	Proportion at 2nd pick.
*El Saff ...	Ashmouni Gedid ...	15–3	3.56	3.97	4.14	3.70	3.60	4.13	3.65	3.16	3.74	0.65	In kantars per fed.
		30–9	95.1	106.1	110.5	98.9	96.4	110.4	97.6	84.5	100.0	17.48	In per cent. (1 pick only.)

TABLE 6.—1931 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE ALONE AND IN COMBINATION WITH SUPERPHOSPHATE. *Layout* : CHEQUER WITH EIGHT REPLICATIONS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Dates of sowing and picking	TREATMENTS No manure	1 P	1N+1P	2N+1P	3N+1P	1 N	1N+2P	1N+3P	Mean	S.E.	Yields
Danasour	Giza 7	11–3	4.68	5.03	5.46	5.62	5.79	5.45	5.60	5.62	5.40	0.15	In kantars per fed.
		4–9	86.7	93.2	103.3	106.3	109.5	103.0	106.0	106.3	100.0	2.73	In per cent.
		26–9	14.6	13.2	16.9	17.2	19.4	14.9	15.0	12.7	—	—	Proportion at 2nd pick.
*Kufur el Raml	Giza 7	28– 2	5.57	5.83	6.22	6.24	6.17	5.94	6.16	6.06	6.00	0.20	In kantars per fed.
		13– 9	92.9	97.1	103.7	104.0	102.9	99.0	102.7	101.1	100.0	3.36	In per cent.
		11–10	8.0	8.5	8.9	8.9	8.6	10.0	8.5	8.6	—	—	Proportion at 2nd pick.
*Siberbai	Giza 7	13– 3	4.06	4.33	4.25	4.52	4.86	4.14	4.45	4.57	4.40	0.19	In kantars per fed.
		16– 9	92.4	98.5	96.7	102.8	110.4	94.2	101.0	103.9	100.0	4.29	In per cent.
		8–10	10.2	10.3	13.1	15.4	15.4	12.6	12.2	10.8	—	—	Proportion at 2nd pick.
Motamadiya ...	Sakel	15–3	2.38	2.52	3.13	3.43	3.54	3.41	3.16	2.95	3.03	0.26	In kantars per fed.
		—	78.6	83.3	103.2	113.2	116.8	112.7	104.3	97.5	100.0	8.73	In per cent.
		—	40.0	36.5	40.6	38.0	46.2	42.8	40.7	44.6	—	—	Proportion at 2nd pick.
Qaha	Foadi	12–3	2.65	3.03	3.56	4.48	5.11	3.83	4.05	4.00	3.87	0.20	In kantars per fed.
		—	68.5	78.3	91.9	115.7	132.1	98.9	104.6	103.4	100.0	5.20	In per cent.
		—	30.5	30.4	25.5	26.6	28.9	26.2	23.9	23.4	—	—	Proportion at 2np pick.

*Beni Saleh ...	Maarad	12– 3	4.21	4.37	4.78	5.06	4.91	4.64	4.65	5.02	4.71	0.21	In kantars per fed.
		16– 9	89.3	92.7	101.5	107.5	104.2	98.4	98.8	106.5	100.0	4.43	In per cent.
		9–10	19.6	18.1	18.9	20.7	23.3	19.2	17.7	17.4	—	—	Proportion at 2nd pick.
Mit Gaber	Maarad	5– 3	4.68	4.68	5.45	5.57	5.73	5.41	5.14	5.27	5.20	0.11	In kantars per fed.
		12– 9	90.1	90.1	104.7	107.1	110.2	104.1	98.9	101.3	100.0	2.06	In per cent.
		7–10	21.9	18.0	18.4	21.1	23.8	20.2	20.7	21.7	—	—	Proportion at 2nd pick.
*Beba	Ashmouni Gedid	21– 2	5.64	5.43	6.26	6.03	5.87	6.00	6.53	6.29	6.04	0.37	In kantars per fed.
		—	93.3	89.9	103.6	99.9	97.3	99.4	108.0	104.1	100.0	6.21	In per cent.
		8–10	8.0	8.8	9.1	10.0	10.3	9.3	10.2	8.1	—	—	Proportion at 2nd pick.
*Helwan	Ashmouni Gedid	7– 3	4.95	4.30	5.03	5.35	5.40	4.67	4.92	4.91	4.88	0.33	In kantars per fed.
		9– 9	101.5	88.2	103.2	109.6	110.6	95.6	100.9	100.6	100.0	6.71	In per cent.
		11–10	19.4	21.4	19.9	22.0	23.0	22.8	21.6	20.7	—	—	Proportion at 2nd pick.
Qalioub	Zagora	5– 3	5.94	6.35	6.87	7.32	7.45	6.59	6.70	6.62	6.76	0.23	In kantars per fed.
		7–10	87.9	94.0	101.8	108.3	110.2	97.5	99.2	98.0	100.0	3.41	In per cent. (1 pick only)
Asyût	Ashmouni Malaki	16–3	7.65	7.53	6.67	6.32	5.14	7.14	6.92	7.10	6.94	0.34	In kantars per fed.
		12–9	110.2	108.4	96.1	91.1	74.1	103.0	99.7	102.3	100.0	4.92	In per cent. (1 pick only)

TABLE 7.—1931 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE ALONE AND IN COMBINATION WITH SUPERPHOSPHATE.

Layout : FOUR RANDOMISED BLOCKS WITH EIGHT TREATMENTS. *Plot size* : 1/24th FEDDAN.

Locality	Variety	Dates of sowing and picking	TREATMENTS: No manure	1 N	2 N	3 N	2 P	1N+2P	2N+2P	3N+2P	Mean	S.E.	Yields
*Qaraqis	Giza 7 ...	17- 3	5.53	5.49	4.99	4.99	4.76	5.33	4.95	5.59	5.20	0.21	In kantars per fed.
		19- 9	106.3	105.6	95.9	95.9	91.6	102.6	95.3	107.5	100.0	4.12	In per cent.
		13-10	7.8	5.8	8.6	10.8	8.7	8.3	9.3	8.8	—	—	Proportion at 2nd pick.
Defra	Giza 7 ...	9- 3	4.97	5.45	5.75	5.81	4.69	5.64	6.06	6.48	5.61	0.24	In kantars per fed.
		29- 9	88.6	97.1	102.5	103.6	83.6	100.6	108.0	115.5	100.0	4.31	In per cent.
		14-10	7.3	9.1	8.9	8.5	6.9	8.1	9.1	8.8	—	—	Proportion at 2nd pick.
*Abu Raqaba ...	Giza 7 ...	10- 3	3.98	4.21	4.55	4.30	4.12	4.04	4.71	4.55	4.31	0.24	In kandars per fed.
		26- 8	92.4	97.9	105.6	99.8	95.6	93.8	109.3	105.6	100.0	5.48	In per cent.
		29- 9	26.8	26.7	25.9	30.1	23.6	25.9	28.3	24.3	—	—	Proportion at 2nd pick.
*El Azab	Ashmouni Gedid ...	17- 3	5.70	6.44	6.52	6.33	5.87	6.50	6.55	6.71	6.33	0.29	In kantars per fed.
		9- 9	90.0	101.7	102.9	100.0	92.7	102.6	103.5	105.9	100.0	4.53	In per cent.
		1-10	6.2	6.5	6.7	6.9	4.9	6.2	5.2	7.5	—	—	Proportion at 2nd pick.

Kufur	Ashmouni Gedid ...	11– 3	5.56	6.02	6.31	6.73	5.45	6.15	6.61	6.74	6.20	0.34	In kantars per fed.
		—	89.7	97.1	101.7	108.5	87.9	99.3	106.6	108.7	100.0	5.41	In per cent.
		—	21.9	23.7	25.7	25.2	21.0	22.9	24.5	26.5	—	—	Proportion at 2nd pick.
Hawaslia... ...	Giza 7 ...	7– 3	3.05	3.62	4.02	4.80	3.30	3.96	4.57	4.34	3.96	0.28	In kantars per fed.
		1– 9	77.0	91.5	101.5	121.2	83.2	100.0	115.4	109.7	100.0	7.41	In per cent.
		22– 9	17.5	17.9	16.6	14.7	8.7	14.9	22.1	16.2	—	—	Proportion at 2nd pick.
*Ezbet Khorshid	Giza 7 ...	2– 4	3.02	2.95	2.91	2.57	2.48	3.12	2.74	2.91	2.84	0.20	In kantars per fed.
		4–10	106.4	104.0	102.3	90.6	87.2	109.8	96.4	102.3	100.0	5.77	In per cent. (1 pick only)

TABLE 8.—1932 EXPERIMENTS (LOWER EGYPT). INCREASING AMOUNTS OF NITRATE IN ONE AND IN TWO DOSES.
Layout : CHEQUER WITH EIGHT REPLICATIONS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS								Mean	S.E.	Yields
				No manure	1 N	One dose			Two doses					
						1·5 N	2 N.	2·5 N	1·5 N.	2 N	2·5 N			
*Shebin el Kom	Ashmouni Gedid ...	Maize	27–2	6.91	7.7	7.35	7.41	7.50	7.54	7.33	7.30	7.09	0.19	In kantars per fed.
			15–9	97.4	99.8	103.7	104.5	105.9	103.9	103.5	102.9	100.0	2.63	In per cent.
			4–10	26.6	28.9	28.3	31.8	32.4	29.8	30.4	29.3	—	—	Proportion at 2 nd pick.
Qaha ...	... Ashmouni Gedid ...	Maize	5–3	5.65	6.59	7.13	7.32	7.35	7.30	7.63	7.85	7.10	0.22	In kantars per fed.
			5–9	79.6	92.6	100.3	103.0	103.5	102.8	107.5	110.6	100.0	3.12	In per cent.
			8–10	14.7	12.5	17.0	15.6	16.4	14.1	15.0	16.0	—	—	Proportion at 2nd pick.
Hehya ...	Giza 7 ...	Maize	14– 3	6.07	7.16	7.20	7.84	7.96	7.36	7.52	7.92	7.36	0.25	In kantars per fed.
			11– 9	82.5	97.3	97.9	104.1	108.1	100.0	102.2	107.6	100.0	3.43	In per cent.
			5–10	25.2	27.4	29.8	29.3	29.2	27.5	29.6	30.1	—	—	Proportion at 2nd pick.
Motamadiya	Sakel ...	—	11–3	3.57	4.27	4.56	4.54	4.29	4.29	4.52	4.68	4.34	0.12	In kantars per fed.
			21– 9	82.3	98.4	105.0	104.6	98.8	98.8	104.2	107.9	100.0	2.85	In per cent.
			20–10	63.6	66.6	67.9	70.1	68.2	68.9	70.9	70.9	—	—	Proportion at 2nd pick.

Siberbai ...	Sakha 4 ...	—	16– 3	4.21	4.65	4.86	4.86	5.19	4.92	5.16	5.06	4.87	0.16	In kantars per fed.
			14– 9	86.4	95.5	99.8	99.8	106.6	101.1	106.0	104.0	100.0	3.29	In per cent.
			12–10	52.1	56.7	60.5	59.8	63.0	59.7	59.7	59.3	—	—	Proportion at 2nd pick.
Sakha	Sakel	Maize	17– 3	3.73	3.89	3.91	4.27	3.99	4.22	4.14	4.06	4.03	0.12	In kantars per fed.
	Domain		18– 9	92.6	96.5	96.9	106.0	98.9	104.8	102.8	100.8	100.0	2.87	In per cent.
	Dedid		19–10	51.1	53.9	54.5	56.5	54.6	56.0	55.6	57.0	—	—	Proportion at 2nd pick.
Kafrel Sheikh	Sakha 4 ...	—	24– 3	4.11	4.48	5.02	4.91	4.43	5.00	5.13	4.97	4.76	0.22	In kantars per fed.
			25–9	86.4	94.1	105.4	103.1	93.1	105.1	107.7	104.4	100.0	4.70	In per cent
			16–10	25.5	28.4	25.3	30.4	32.6	28.9	28.5	32.6	—	—	Proportion at 2nd pick.
Zebeida ...	Giza 7 ...	Maize	11– 3	5.00	5.72	6.13	6.34	6.40	6.05	6.06	6.46	6.02	0.12	In kantars per fed.
			16– 9	83.1	94.9	101.8	105.2	106.3	100.5	100.8	107.3	100.0	2.00	In per cent.
			12–10	35.9	34.4	34.2	35.8	36.7	36.0	34.8	36.6	—	—	Proportion at 2nd pick.
Beni Qorra (Upper Egypt)	Ashmouni Gedid ...	Fallow	5– 3	7.54	8.94	9.32	8.83	9.65	8.16	9.43	9.75	8.95	0.43	In kantars per fed.
			12– 9	84.3	99.9	104.1	98.6	107.9	91.2	105.4	108.9	100.0	8.41	In per cent.
			2–10	29.5	28.4	27.8	28.8	29.6	27.2	27.3	29.0	—	—	Proportion at 2nd pick.

TABLE 9.—1932 EXPERIMENTS (UPPER EGYPT.) INCREASING AMOUNTS OF NITRATE IN ONE AND IN TWO DOSES.

Layout: CHEQUER WITH EIGHT REPLICATIONS. *Plot size*: 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS								Mean	S.E.	Yields
				No manure	1 N	One dose			Two doses					
						2 N	3 N	4 N	2 N	3 N	4 N			
Beba ...	Ashmouni Gedid.	Maize	29–2	4.54	4.94	5.60	5.80	5.89	5.80	5.37	5.56	5.44	0.27	In kantars per fed.
			13–9	83.5	90.8	103.0	106.5	108.3	106.5	98.6	102.2	100.0	4.91	In per cent.
			11–10	3.5	3.9	4.3	5.2	5.7	4.9	5.0	5.4	—	—	Proportion at 2nd pick.
Kufur ...	Ashmouni Gedid.	Maize	6–3	5.27	6.70	7.43	8.19	8.51	7.35	7.46	8.65	7.45	0.32	In kantars per fed.
			7–9	70.7	89.9	99.7	109.9	114.2	98.7	100.2	116.1	100.0	4.29	In per cent.
			20–10	11.5	16.4	16.2	19.6	17.7	13.9	12.6	22.2	—	—	Proportion at 2nd pick.
Hawaslia	Ashmouni Gedid.	Maize	21–2	3.37	4.57	4.97	4.89	5.30	5.06	5.67	5.27	4.89	0.29	In kantars per fed.
			20–9	68.8	93.5	101.6	100.0	108.4	103.6	116.0	107.8	100.0	5.87	In per cent.
			2–10	21.7	25.7	26.2	31.8	33.2	27.6	28.8	37.5	—	—	Proportion at 2nd pick.

TABLE 10.—1932 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE ALONE AND IN COMBINATION WITH SUPERPHOSPHATE.
Layout : FOUR RANDOMISED BLOCKS WITH EIGHT TREATMENTS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS								Mean	S.E.	Yields
				No manure	1N	2N	3N	2P	2P+1N	2P+2N	3P+2N			
Hawaslia ...	Ashmouni Gedid ...	Maize	24–2	4.00	4.76	4.84	4.97	4.80	5.03	6.38	6.02	5.10	0.27	In kantars perfed.
			1–9	78.4	93.4	94.8	97.5	94.1	98.6	125.1	118.0	100.0	5.32	In per cent.
			22–9	39.5	42.4	41.0	44.5	29.8	22.7	38.5	38.9	—	—	Proportion at 2nd pick.
Kufur	Ashmouni Gedid ...	Maize	8–3	6.71	7.51	8.31	10.32	7.26	8.33	8.61	9.79	8.35	0.30	In kantars per fed.
			15–9	80.3	89.9	99.5	123.7	86.9	99.7	103.1	117.3	100.0	3.56	In per cent.
			24–10	7.4	7.9	7.3	7.0	6.8	7.1	7.1	7.0	—	—	Proportion at 2nd pick.
El Azab ...	Ashmouni Gedid ...	Maize and Berseem	3–3	5.62	6.46	6.67	7.93	4.27	6.17	7.20	7.89	6.52	0.36	In kantars per fed.
			29–8	86.2	99.1	102.3	121.6	65.5	94.7	110.5	118.2	100.0	5.47	In per cent.
			20–9	9.2	13.3	18.3	20.9	13.8	13.6	15.6	20.8	—	—	Proportion at 2nd pick.
*Giza	Ashmouni Gedid ...	Maize and Berseem	17–3	7.66	8.91	7.54	8.15	6.33	7.85	7.43	7.96	7.73	0.60	In kantars per fed.
			28–8	99.1	115.4	97.6	105.5	81.8	101.6	96.1	103.0	100.0	7.71	In per cent.
			27–9	14.9	21.8	23.7	26.2	24.1	23.3	26.2	25.3	—	—	Proportion at 2nd pick.

Burdein ...	Maarad ...	—	13–3	5.79	6.84	8.15	8.80	5.91	7.68	7.81	8.69	7.46	0.40	In kantars per fed.
			20–9	77.7	91.7	109.3	118.0	79.2	102.9	104.7	116.5	100.0	5.29	In per cent.
			27–10	15.8	21.8	23.4	27.5	16.8	22.8	23.7	25.9	—	—	Proportion at 2nd pick.
Defra ...	... Giza 7 ...	Berseem	15–3	4.82	5.60	6.19	6.31	4.94	5.91	6.17	6.36	5.78	0.15	In kantars per fed.
			8–9	83.4	96.9	107.1	109.1	85.4	102.2	106.8	110.1	100.0	2.57	In per cent.
			—	42.3	43.4	45.8	47.1	37.1	43.2	43.5	47.3	—	—	Proportion at 2nd pick.
Qaraqis ...	Giza 7 ...	Berseem	20–3	6.89	7.59	7.65	7.56	7.46	7.37	8.35	8.70	7.70	0.35	In kantars per fed.
			16–9	89.5	98.5	99.4	98.1	96.9	95.7	108.5	113.0	100·0	4·50	In per cent.
			8–10	40.1	40.6	42.3	45.0	41.7	37.1	47.1	45.6			Proportion at 2nd pick.

TABLE 11.—1932 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE IN COMBINATION WITH SUPERPHOSPHATE.

Layout: EIGHT RANDOMISED BLOCKS WITH EIGHT TREATMENTS. *Plot size*: 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS: No manure	1 P	1N+1P	2N+1P	3N+1P	1 N	1N+2P	1N+3P	Mean	S.E.	Yields
*Sakha ...	Sakel D. Gedid	Maize	17–3	3.32	3.19	3.62	3.75	3.47	3.48	3.70	3.89	3.55	0.18	In kantars per fed.
			18–9	93.5	89.9	102.0	105.5	97.7	97.9	104.2	109.6	100.0	5.18	In per cent.
			18–10	53.6	48.3	50.5	53.8	56.6	55.3	49.4	52.8	—	—	Proportion at 2nd pick.
Motamadiya	Sakel ...	Berseem	11–3	4.22	4.00	4.60	4.94	4.95	4.56	4.62	4.37	4.56	0.18	In kantars per fed.
			21–9	92.6	87.7	101.0	108.3	108.6	100.0	101.3	95.7	100.0	3.86	In per cent.
			21–10	53.4	55.2	56.6	60.5	57.7	56.4	57.0	56.7	—	—	Proportion at 2nd pick.
Siberbai (R.W.)	Sakha 4 ...	Berseem	16–3	4.32	4.92	5.49	5.57	5.78	5.06	5.35	5.30	5.18	0.18	In kantars per fed.
			16–9	83.4	95.0	106.0	107.5	111.6	97.8	103.3	102.4	100.0	3.52	In per cent.
			12–10	57.0	55.5	58.1	61.8	63.8	57.1	54.0	50.3	—	—	Proportion at 2nd pick.
Siberbai ...	Sakha 4 ...	Berseem	29–2	3.81	3.43	4.03	4.70	4.60	3.97	3.99	4.05	4.09	0.19	In kantars per fed.
			13–9	93.2	83.9	98.6	114.9	112.6	97.0	97.4	99.0	100.0	4.75	In per cent.
			27–9	57.1	56.9	60.2	61.5	64.8	60.4	59.8	60.8	—	—	Proportion at 2nd pick.

Kafr El Sheikh	Sakha 4 ...	Berseem	24–3	4.40	4.54	4.13	4.21	4.45	4.38	4.13	4.56	4.40	0.12	In kantars per fed.
			24–9	100.0	103.2	93.9	95.8	101.1	99.6	93.8	103.6	100.0	2.64	In per cent.
			16–10	25.6	25.2	26.8	28.6	28.5	27.2	28.4	26.5	—	—	Proportion at 2nd pick.
Sherbin ...	Sakha 4 ...	Berseem	26–3	4.79	4.87	5.78	6.38	7.53	5.54	5.14	5.05	5.63	0.32	In kantars per fed.
			22–9	85.2	86.6	102.7	113.6	133.6	98.4	91.4	89.7	100.0	5.65	In per cent.
			26–10	42.7	36.8	46.7	50.5	55.5	46.1	37.4	40.6	—	—	Proportion at 2nd pick.
*Shubrakheit	Sakel ...	Beans	13–3	4.16	4.11	4.11	4.25	3.99	3.99	3.84	4.03	4.07	0.20	In kantars per fed.
			14–9	102.2	101.0	101.0	104.5	97.9	97.9	94.4	99.1	100.0	4.91	In per cent.
			15–10	61.8	65.3	65.6	67.9	73.3	66.5	67.4	66.9	—	—	Proportion at 2nd pick.
*Nashart ...	Sakha 4 ...	Maize	18–3	3.05	2.97	3.60	3.59	3.51	3.22	3.53	3.51	3.36	0.19	In kantars per fed.
			22–9	90.7	88.4	107.2	106.8	104.4	95.9	104.9	104.4	100.0	5.74	In per cent.
			9–10	69.8	71.2	73.1	81.0	77.4	73.9	73.0	68.3	—	—	Proportion at 2nd pick.
*Banawan...	Sakel ...	Berseem	28–3	3.57	3.26	3.97	3.91	4.45	3.81	4.02	4.14	3.86	0.25	In kantars per fed.
			29–7	92.5	84.3	102.8	101.2	115.2	98.7	104.0	107.3	100.0	6.47	In per cent.
			14–10	36.4	38.5	40.4	38.6	46.1	37.3	40.7	41.0	—	—	Proportion at 2nd pick.
Beni Saleh	Maarad ...	Maize	7–3	5.24	5.43	6.41	6.65	7.03	6.56	6.17	6.43	6.28	0.22	In kantars per fed.
			14–9	83.4	86.4	102.1	105.9	112.0	104.4	98.3	102.4	100.0	3.45	In per cent.
			5–10	45.5	45.6	47.0	51.8	54.0	48.2	47.3	47.7	—	—	Proportion at 2nd pick.

TABLE 11 (*contd.*).—1932 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE IN COMBINATION WITH SUPERPHOSPHATE.
Layout : EIGHT RANDOMISED BLOCKS WITH EIGHT TREATMENTS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Previous crop	Dates of sowing and picking	TREATMENTS No manure	1 P	1N+1P	2N+1P	3N+1P	1 N	1N+2P	1N+3P	Mean	S.E.	Yields
*Hehya ...	Giza 7 ...	Maize	14– 3 14– 9 4–10	4.05 79.4 35.3	4.68 91.8 38.0	5.24 102.7 32.4	5.14 100.9 42.0	5.87 115.2 38.4	4.75 93.3 35.8	5.38 105.5 35.4	6.08 119.2 31.9	5.10 100.0 —	0.44 8.68 —	In kantars per fed. In per cent Proportion at 2nd. pick.
Defra	Giza 7 ...	Maize & Berseem c.c.	14– 3 8– 9 6–10	3.62 85.3 24.4	3.64 85.7 25.2	4.17 98.2 35.7	4.86 114.2 39.8	5.34 125.5 39.4	4.12 97.0 36.1	4.19 98.6 34.7	4.21 99.0 34.1	4.25 100.0 —	0.12 2.77 —	In kantars per fed. In per cent. Proportion at 2nd pick.
Mit Bera	Ashmouni Gedid...	Maize	4– 3 12– 9 6–10	6.54 95.6 6.6	6.34 92.6 8.0	6.94 101.4 7.1	6.86 100.3 8.8	7.32 107.0 9.6	6.54 95.6 7.8	7.05 103.1 8.1	7.00 102.3 7.5	6.84 100.0 —	0.16 2.28 —	In kantars per fed. In per cent. Proportion at 2nd pick.
Qaha	Ashmouni Gedid	Maize	5– 3 6– 9 10–10	5.95 89.9 11.4	6.03 91.1 13.7	6.46 97.6 11.6	7.13 107.7 12.3	7.57 114.4 15.3	6.61 99.7 11.1	6.80 102.6 11.4	6.80 102.6 11.0	6.62 100.0 —	0.27 4.03 —	In kantars per fed. In per cent. Proportion at 2nd pick.

*Hawaslia	Ashmouni Gedid...	Maize	22– 2	3.94	4.30	4.76	5.35	5.41	4.62	4.94	5.13	4.90	0.40	In kantars per fed.
			31– 8	80.4	87.8	97.2	109.2	110.5	94.3	100.8	104.7	100.0	8.12	In per cent
			3–10	18.1	16.6	23.3	24.9	32.8	25.8	26.4	23.5	—	—	Proportion at 2n-pick.
*Minia	Ashmouni Gedid...	Fallow	8– 3	6.37	6.00	6.87	7.76	7.57	6.54	6.45	6.97	6.81	0.47	In kantars per fed.
			20– 8	93.5	88.1	101.0	114.0	111.2	96.1	94.6	102.4	100.0	6.88	In per cent
			14–9	35.2	36.5	37.6	41.5	44.9	41.3	36.7	43.1	—	—	Proportion at 2nd pick.
*Kom Ombo	Giza 3 ...	Beans	6– 3	7.14	7.87	8.38	7.02	7.52	7.49	7.46	7.87	7.61	0.47	In kantars per fed.
			25– 8	93.9	103.5	110.1	92.2	98.9	98.5	98.1	103.5	100.0	6.14	In per cent.
			15–9	24.0	33.9	34.5	31.2	27.9	30.9	33.2	27.0	—	—	Proportion at 2nd pick.
Beba...	Ashmouni Gedid...	Maize	2– 3	3.87	3.84	4.87	5.14	5.68	4.59	5.35	4.70	4.70	0.19	In kantars per fed.
			12– 9	82.4	81.7	103.7	109.4	121.0	97.6	113.8	100.0	100.0	4.00	In per cent.
			10–10	—	—	—	—	—	—	—	—	—	—	Low yield at 2nd pick.
Tersa ...	Ashmouni	Cabbage	18– 3	3.27	4.08	3.87	4.11	3.83	3.99	3.62	3.54	3.73	—	In kantars per fed.
	Gedid...	—	11– 9	87.7	109.3	103.9	110.2	102.6	106.8	97.0	94.9	100.0	—	In per cent. (1 pick only)

TABLE 12.—1932 EXPERIMENTS. INCREASING AMOUNTS OF NITRATE
Layout : SIX RANDOMISED BLOCKS WITH FIFTEEN PLOTS

Locality and variety	Dates of sowing and picking	TREAT							
		No manure	1N	2N	3N	4N	2N+1P	3N+1P	4N+1P
Sakha	18– 3	3.39	3.47	3.89	3.43	3.62	3.66	3.75	3.81
Sakel D. Gedid...	18– 9	91.7	93.8	105.3	92.7	97.8	99.0	101.3	103.0
	7–10	67.8	65.3	65.8	70.4	66.7	68.2	71.2	66.7
Sids	28– 3	3.11	3.15	3.20	3.13	3.53	3.35	3.70	3.03
Ashmouni Gedid	24– 9	92.9	94.2	95.4	93.5	105.5	100.0	110.6	90.3
	19–10	10.6	12.8	12.6	11.5	13.2	15.2	18.9	17.5
Mallawi	16– 3	3.92	4.81	6.20	7.05	6.50	6.15	6.96	7.30
Ashmouni Gedid	6– 9	65.5	80.3	103.7	117.8	108.7	102.6	116.4	122.1
	4–10	18.1	17.2	21.8	24.3	31.0	22.1	25.5	29.9
Matâna	10– 3	1.97	3.45	4.72	6.01	6.92	4.72	5.46	7.45
Giza 7...	5– 9	36.7	64.3	87.9	111.9	129.0	87.9	101.7	138.7
	3–10	13.5	8.0	10.8	12.7	12.5	8.5	7.0	11.4

ALONE AND IN COMBINATION WITH THREE LEVELS OF SUPERPHOSPHATE.
PER BLOCK (*Two control plots*). *Plot size:* 1/40th FEDDAN.

MENTS						Mean	S.E.	Yields
2N+2P	3N+2P	4N+2P	2N+3P	3N+3P	4N+3P			
3.87	3.53	3.79	4.19	4.15	3.70	3.70	0.17	In kantars per feddan.
104.7	95.5	102.4	113.3	112.1	100.0	100.0	4.71	In per cent.
68.3	70.7	63.1	68.2	67.9	62.3	—	—	Proportion at 2nd. pick.
3.32	3.39	3.87	2.96	3.15	4.15	3.35	0.47	In kantars per feddan.
99.2	101.1	115.6	88.5	94.2	124.0	100.0	14.02	In per cent.
10.8	13.8	13.1	15.7	16.1	10.2	—	—	Proportion at 2nd. pick.
5.59	6.61	6.48	5.69	6.03	6.46	5.98	0.45	In kantars per feddan.
93.5	110.4	108.3	95.2	100.9	108.0	100.0	7.46	In per cent.
25.0	27.2	29.7	21.6	23.5	29.8	—	—	Proportion at 2nd. pick.
4.70	6.39	8.04	4.83	6.92	7.03	5.37	0.28	In kantars per feddan.
87.5	119.0	149.7	89.9	128.6	130.9	100.0	5.24	In per cent.
7.2	12.9	13.2	7.9	11.0	13.0	—	—	Proportion at 2nd. pick.

TABLE 13.—1933 EXPERIMENTS (UPPER EGYPT).

COMBINATION WITH TWO LEVELS OF SUPERPHOSPHATE. *Layout:* SIX

Locality variety and previous crop	Dates of sowing and picking	TREAT							
		No manure	1N	2N	3N	4N	1N+1P	2N+1P	3N+1P
Matania	5– 3	8.02	9.48	10.10	11.66	11.47	9.80	10.64	11.62
Ashmouni Gedid	9– 9	78.2	92.4	98.4	113.7	111.8	95.5	103.8	113.3
Wheat	17–10	14.0	18.1	19.9	37.4	28.2	19.2	24.0	26.4
Mallawi	21– 2	7.26	8.36	9.42	9.66	9.35	8.04	9.33	9.78
Giza 19	16– 9	80.8	93.0	104.8	107.4	104.1	89.5	103.9	108.8
Maize	11–10	10.5	15.4	14.6	17.1	19.2	15.8	13.6	17.3
Kufur	14– 3	5.63	7.70	8.21	8.80	7.92	7.61	8.15	9.29
Ashmouni Gedid	11–9	70.6	95.1	103.0	110.4	99.3	97.7	102.2	116.5
Maize	12–10	28.9	34.3	39.2	37.0	43.8	33.4	34.3	36.0
Matâna	22– 2	5.82	7.07	8.23	8.66	8.78	7.45	7.77	8.38
Giza 3	26– 8	77.1	93.7	109.1	114.7	116.4	98.7	103.0	111.1
Maize	1– 9	8.0	11.1	11.6	15.2	19.3	9.7	10.4	14.6
Kom Ombo	19– 2	4.81	5.59	6.03	6.62	6.41	5.59	6.27	6.33
Giza 3	–	80.6	93.7	101.1	111.1	107.5	93.7	105.0	106.1
Maize	–	—	—	—	—	—	—	—	—
El Azab	4– 3	5.84	7.62	7.05	8.02	6.90	7.09	6.41	6.67
Ashmouni Gedid	1– 9	84.8	110.7	102.4	116.5	100.2	103.0	93.1	96.8
Rice	22– 9	10.5	15.0	20.1	27.4	31.9	15.2	23.1	25.4
*Sids	28– 2	4.09	4.38	4.36	4.17	4.02	4.53	4.25	4.95
Giza 2	9– 9	93.4	100.2	99.7	95.4	92.0	103.6	97.3	113.2
Wheat	22–10	25.4	36.7	31.1	33.5	35.3	31.3	33.8	33.8
*Qimn el Arous	24– 2	6.75	7.49	9.02	7.70	7.81	7.81	7.83	8.30
Ashmouni Gedid	12– 9	86.4	95.9	115.4	68.6	100.0	100.0	100.3	106.2
Berseem	18–10	10.7	15.3	13.2	16.8	20.3	14.4	18.7	16.1
Nazlet el Simman	7– 3	5.17	6.14	7.30	7.34	7.49	5.88	6.67	6.69
Ashmouni Gedid	27– 8	78.3	93.1	110.8	111.4	113.6	89.2	101.1	101.5
Maize and Berseem	—	—	—	—	—	—	—	—	—
Nag Hammadi	22– 2	5.10	5.14	5.62	6.07	6.20	5.90	6.47	5.18
Ashmouni	30– 9	—	—	—	—	—	—	—	—
Maize	—	—	—	—	—	—	—	—	—
Ayat	—	3.70	5.68	4.81	4.84	3.88	5.95	4.18	4.28

INCREASING AMOUNTS OF NITRATE ALONE AND IN

RANDOMISED BLOCKS WITH FIFTEEN TREATMENTS. *Plot size :* 1/40th FEDDAN.

MENTS							Mean	S.E.	Yields
N+1P	1N+2P	2N+2P	3N+2P	4N+2P	1P	2P			
12.32	9.06	10.31	11.34	11.94	7.96	8.23	10.2	0.30	In kantars per feddan.
120.0	88.3	100.4	110.0	116.3	77.6	80.2	100.0	2.97	In per cent.
29.9	15.2	25.1	30.2	31.7	16.2	12.6	—	—	Proportion at 2nd Pick.
10.54	7.87	9.10	10.46	10.69	7.51	7.41	8.99	0.40	In kantars per feddan.
117.3	87.6	101.3	116.3	118.9	83.6	82.4	100.0	4.43	In per cent.
17.3	13.7	15.8	17.2	17.0	11.3	11.4	—	—	Proportion at 2nd pick.
9.15	7.22	8.47	8.89	9.34	6.50	6.69	7.97	0.45	In kantars per feddan.
114.7	90.5	106.2	111.5	117.0	81.5	83.9	100.0	5.70	In per cent.
41.4	30.8	37.5	31.0	41.3	28.3	30.4	—	—	Proportion at 2nd pick.
8.61	6.90	7.60	8.32	8.76	5.50	5.38	7.55	0.31	In kantars per feddan.
114.2	91.5	100.7	110.2	116.1	72.9	71.2	100.0	4.05	In per cent.
17.2	9.2	14.2	17.8	18.8	8.8	11.0	—	—	Proportion at 2nd pick.
6.22	6.67	6.14	6.79	6.56	5.33	4.09	5.97	0.44	In kantars per feddan.
104.3	111.8	102.9	113.9	110.0	89.5	68.5	100.0	7.45	In per cent cent.
—	—	—	—	—	—	—	—	—	Proportion at 2nd pick.
7.62	6.44	6.88	6.46	8.85	5.61	5.86	6.89	0.58	In kantars per feddan.
110.7	93.5	99.9	93.8	128.5	81.4	85.1	100.0	8.47	In per cent.
26.4	14.8	20.3	21.0	29.4	11.3	10.5	—	—	Proportion at 2nd pick.
4.53	3.96	3.87	4.81	5.48	4.00	4.19	4.37	0.54	In kantars per faddan.
103.6	90.5	88.6	109.8	125.3	91.5	95.8	100.0	12.27	In per cent.
35.1	23.0	39.9	34.8	39.0	27.0	29.8	—	—	Proportion at 2nd pick.
7.75	8.00	8.04	8.68	7.58	7.58	6.84	7.81	0.43	In kantars per feddan.
99.2	102.4	103.0	111.1	97.0	97.0	87.5	100.0	5.49	In per cent.
18.0	12.4	16.1	16.8	21.0	13.7	10.5	—	—	Proportion at 2nd pick.
7.34	6.16	7.13	7.01	7.79	5.21	5.57	6.59	0.25	In kantars per feddan.
111.3	93.4	108.2	106.3	118.1	79.0	84.4	100.0	3.79	In per cent.
—	—	—	—	—	—	—	—	—	(One pick only).
6.03	5.82	5.96	6.03	6.20	4.76	5.41	—	—	In kantars per feddan.
—	—	—	—	—	—	—	—	—	(One pick only).
—	—	—	—	—	—	—	—	—	
3·67	5.76	5.13	5.37	4.57	5.95	5.39	—	—	In kantars per feddan.

TABLE 14.—1933 EXPERIMENTS (LOWER EGYPT). INCREASING AMOUNTS OF

Layout : SIX RANDOMISED BLOCKS WITH TWELVE

Locality	Variety	Previous crop	Dates of sowing and picking	TREAT				
				No manure	1N	2N	3N	1N+1P
Gimmeiza	Giza 7 ...	Maize ...	8– 3	5.27	6.07	6.99	7.09	6.24
			19– 9	80.7	93.0	107.0	108.5	95.6
			26–10	64.7	68.7	70.0	75.5	68.2
Sakha	Sakel D. Gedid ... "Sakha7"	Rice ...	21– 3	2.92	3.17	2.56	3.43	4.76
			3– 9	64.4	70.0	56.4	75.6	105.0
			24–10	36.3	53.7	52.9	40.7	29.3
Mit Gaber	Nahda ...	Rice ...	8– 3	4.70	5.17	5.40	5.76	5.42
			19– 9	88.6	97.4	101.8	108.5	102.1
			22–10	36.5	39.4	46.3	47.1	42.6
Shubra el Sharkia ...	Sakel ...	Rice ...	16– 3	3.11	3.20	3.60	2.73	4.00
			24– 9	79.1	81.3	91.5	69.4	101.7
			16–10	62.6	68.9	65.9	71.3	57.7
Muwagid	Zagora ...	Berseem...	22– 3	3.15	4.49	5.21	5.67	4.83
			3–10	62.2	88.5	102.7	111.1	95.2
			18–10	36.2	29.7	30.5	30.6	34.7
*Halawat	Giza 7 ...	Wheat ... then ... Fallow ...	16– 3	3.75	4.00	4.09	3.73	4.23
			17– 9	89.3	95.4	97.4	88.8	100.9
			12–10	30.5	34.9	31.6	35.8	30.5
Bassandila	F. Fuzzy Sakel ...	Rice ...	1– 3	5.42	6.29	6.41	6.18	6.16
			25– 9	86.8	100.7	102.7	99.0	98.6
			22–10	34.8	35.7	29.4	30.8	32.0
Abou Raqaba	Ashmouni Gedid ...	Wheat & Berseem.	2– 3	6.84	7.64	8.42	8.30	7.39
			28– 8	87.4	97.6	107.6	106.0	94.4
			2–10	58.2	60.7	62.8	63.3	58.5
Mehallat Subk	Ashmouni Gedid ...	Maize ...	28– 2	7.07	7.89	8.98	9.27	7.54
			29– 8	86.0	96.0	109.1	112.8	91.0
			16–10	59.9	65.7	65.8	69.4	66.0
*Kafr el Sheikh Attia...	Sakel ...	Rice & Berseem.	22– 3	5.00	6.10	5.63	6.33	5.93
			26– 9	88.8	108.3	100.0	112.5	105.3
			13–10	34.0	35.1	43.6	42.8	36.4

NITRATE ALONE AND IN COMBINATION WITH TWO LEVELS OF SUPERPHOSPHATE.

TREATMENTS. *Plot size*: 1/40th FEDDAN.

MENTS							Mean	S.E.	Yields
2N+1P	3N+1P	1N+2P	2N+2P	3N+2P	1P	2P			
7.03	7.79	6.27	6.90	7.70	5.44	5.57	6.53	0.21	In kantars per feddan.
107.6	119.3	96.0	105.6	118.0	83.3	85.3	100.0	3.22	In per cent.
72.3	74.7	65.2	70.9	73.4	71.2	65.8	—	—	Proportion at 2nd pick.
5.10	5.27	5.50	6.05	6.03	4.53	5.12	4.54	0.28	In kantars per feddan.
112.4	116.1	121.3	133.4	132.9	99.8	112.9	100.0	6.26	In per cent.
34.0	35.3	25.8	31.5	33.3	29.0	22.0	—	—	Proportion at 2nd pick.
5.50	5.78	5.42	5.74	5.99	4.38	4.42	5.31	0.23	In kantars per feddan.
103.7	108.9	102.1	107.1	112.9	82.6	83.4	100.0	4.29	In per cent.
43.8	45.4	38.7	41.7	46.6	42.0	39.2	—	—	Proportion at 2nd pick.
4.76	4.59	4.33	4.57	5.10	3.79	3.43	3.93	0.23	In kantars per feddan.
121.1	116.8	109.7	116.2	129.7	96.4	87.2	100.0	5.83	In per cent.
60.0	64.5	54.9	63.0	63.1	50.3	50.0	—	—	Proportion at 2nd pick.
5.25	5.95	5.04	5.80	7.20	4.15	4.11	5.07	0.44	In kantars per feddan.
103.6	117.3	99.4	114.4	142.0	81.8	81.0	100.0	8.71	In per cent.
28.2	29.9	26.9	28.8	28.8	30.6	32.5	—	—	Proportion at 2nd pick.
4.61	4.30	4.42	4.38	4.66	4.04	4.13	4.20	0.28	In kantars per feddan.
110.0	102.4	105.4	104.4	111.0	96.4	98.4	100.0	6.64	In per cent.
33.0	35.0	30.6	33.8	30.9	30.9	30.6	—	—	Proportion at 2nd pick.
6.54	7.20	6.29	6.48	6.54	5.52	5.90	6.24	0.32	In kantars per feddan.
104.8	115.3	100.7	103.7	104.8	88.5	94.6	100.0	5.07	In per cent.
34.0	39.3	35.4	33.7	33.3	35.3	38.0	—	—	Proportion at 2nd pick.
8.47	8.61	7.60	7.85	8.61	7.20	7.01	7.83	0.18	In kantars per feddan.
108.2	110.0	97.1	100.3	110.0	92.0	89.5	100.0	2.34	In per cent.
65.0	66.1	59.9	61.7	62.6	58.5	58.3	—	—	Proportion at 2nd pick.
8.76	9.08	7.85	8.72	9.19	7.24	7.09	8.22	0.27	In kantars per feddan.
106.6	110.5	95.5	106.1	111.8	88.0	86.2	100.0	3.23	In per cent.
69.3	71.3	65.8	64.5	69.8	60.5	60.0	—	—	Proportion at 2nd pick.
5.90	6.46	4.55	6.10	6.03	4.57	5.00	5.63	0.57	In kantars per feddan.
104.9	114.7	80.9	108.3	107.2	81.2	88.8	100.0	10.17	In per cent.
50.9	47.2	33.0	39.6	44.6	38.4	36.4	—	—	Proportion at 2nd pick.

TABLE 14 (*contd.*) 1933 EXPERIMENTS (LOWER EGYPT). INCREASING AMOUNTS OF
Layout: SIX RANDOMISED BLOCKS WITH TWELVE

Locality	Variety	Previous crop	Date of sowing and picking	TREAT: No manure	IN	2N	3N	1N+1P
Sibirbai	Ashmouni Gedid ...	—	22- 3 5- 9 3-10	3.11 74.5 55.1	3.77 90.2 57.3	4.38 104.9 60.4	4.85 116.0 66.4	4.09 97.9 58.5
El Manshia (Benha) ...	Ashmouni Gedid ...	Maize ...	5- 3 12- 9 —	5.27 80.0 22.5	6.39 97.0 21.9	6.90 104.7 18.8	7.28 110.5 19.4	6.67 101.1 18.4
Zebeida	Giza 7 ...	Maize ...	6- 3 9- 9 2-10	6.27 80.4 47.0	7.89 101.4 45.6	8.13 104.4 52.4	8.81 113.0 56.7	7.24 93.0 43.6
Qaraqis	Giza 7 ...	Rice ...	7- 3 25- 9 18-10	2.65 76.5 42.4	3.30 95.5 39.1	3.45 99.8 45.6	3.98 115.1 51.6	3.49 101.1 43.0
Qaha	Ashmouni Gedid ...	Maize ...	5- 3 5- 9 —	5.50 81.2 23.5	6.77 99.9 24.1	7.09 104.6 22.1	7.39 109.0 29.9	6.45 95.3 22.6
Motamadiya	Sakha 4 ...	Rice ...	19- 3 24- 9 15-10	3.35 73.0 46.2	4.66 101.6 59.1	4.97 108.5 60.4	5.42 118.2 55.1	4.57 99.8 57.9
Defra	Giza 7 ...	Maize ...	28- 2 8- 9 13-10	5.80 82.0 54.4	6.65 93.9 55.8	7.32 103.5 60.7	8.00 113.1 63.2	6.86 96.9 60.8
*Nabaroh	Maarad ...	Rice & Berseem.	30- 3 3-10 24-10	4.06 98.2 40.6	3.89 94.1 46.7	4.61 111.5 42.7	3.58 86.5 38.5	4.15 100.3 42.9
Mashal	Maarad ...	Rice ...	21- 3 27- 9 4-11	5.51 84.0 49.4	6.68 101.6 50.2	6.94 105.6 54.3	7.39 112.3 63.9	6.27 95.3 48.3

NITRATE ALONE AND IN COMBINATION WITH TWO LEVELS OF SUPERPHOSPHATE TREATMENTS. *Plot size*: 1/40th FEDDAN.

MENTS							Mean	S.E.	Yields
2N+IP	3N+IP	IN+2P	2N+2P	3N+2P	IP	2P			
4.23	5.31	3.58	4.76	5.06	3.51	3.47	4.18	0.28	In kantars per feddan.
101.4	127.2	85.6	114.0	121.1	84.1	83.1	100.0	6.70	In per cent.
61.0	65.0	58.0	65.3	68.6	48.8	53.2	—	—	Proportion at 2nd pick.
7.24	7.43	6.46	6.86	7.20	5.52	5.88	6.59	0.27	In kantars per feddan.
109.8	112.7	97.9	104.0	109.2	83.8	89.3	100.0	4.24	In per cent.
22.5	25.9	23.0	23.5	24.1	20.3	20.1	—	—	Proportion at 2nd pick.
8.21	9.17	7.34	8.47	8.54	6.79	6.71	7.79	0.55	In kantars per feddan.
105.4	117.7	94.3	108.7	108.4	87.3	86.2	100.0	7.02	In per cent.
47.7	55.7	46.4	50.8	55.1	43.3	38.8	—	—	Proportion at 2nd rpick.
3.77	4.13	3.35	3.70	3.94	2.86	2.86	3.46	0.17	In kantars per feddan.
109.0	119.4	96.8	107.2	113.9	82.7	82.7	100.0	5.01	In per cent.
43.3	50.3	38.0	42.9	50.0	40.8	40.0	—	—	Proportion at 2nd pick.
7.47	7.58	6.90	6.94	7.41	5.76	6.10	6.78	0.31	In kantars per feddan.
101.2	111.8	101.8	102.4	109.3	84.9	89.9	100.0	4.51	In per cent.
21.5	26.0	25.5	21.3	24.0	23.9	25.1	—	—	Proportion at 3rd pick.
4.78	4.81	4.63	4.89	5.19	3.83	3.89	4.58	0.26	In kantars per feddan.
104.4	104.8	100.1	106.7	113.2	83.6	85.0	100.0	5.67	In per cent.
61.9	63.5	58.0	65.8	60.8	53.6	51.6	—	—	Proportion at 2nd pick.
7.32	8.09	6.69	7.79	8.02	6.27	6.10	7.08	0.16	In kantars per feddan.
103.5	114.3	94.6	110.1	113.4	88.6	86.2	100.0	2.27	In per cent.
59.5	61.5	53.8	58.4	60.7	56.4	52.1	—	—	Proportion at 2nd pick.
3.79	3.98	4.87	3.68	4.06	4.51	4.47	4.14	0.32	In kantars per feddan.
91.6	96.3	117.6	89.0	98.2	109.0	107.9	100.0	7.77	In per cent.
43.6	45.8	44.8	39.7	41.1	39.0	38.9	—	—	Proportion at 2nd pick.
6.61	7.49	6.44	6.82	7.43	5.65	5.69	6.58	0.22	In kantars per feddan.
100.4	113.9	97.9	103.6	113.0	85.9	86.6	100.0	3.36	In per cent.
53.5	59.0	52.0	56.2	59.3	47.2	46.1	—	—	Proportion at 2nd pick.

TABLE 15.—YEAR 1933.
Layout : FIVE-SIDED LATIN SQUARE.
($1\frac{1}{2}$ K. means sulphate of potash at

Locality	Variety	Previous crop	Dates of sowing and picking	TREAT	
				No manure	$1\frac{1}{2}$ N
Kufur el Raml ...	Ashmouni Gedid ...	Maize	22–2 5–9 & 11–10	8.13 88.6	9.75 106.3
Bassandila	F. Fuzz ... ... Sakel	Berseem ... ... (c.c.)	15–3 25–9 & 22–10	6.27 89.4	7.90 112.5
Shubra Sindi ...	Maarad	Rice	20–3 28–9 & 19–10	6.27 87.8	7.57 105.9
El Manshia (Benha)	Maarad	Maize	4–3 1–10 & ?	4.70 78.7	5.81 97.4
Tala	Ashmouni ... Malaki... ...	Maize	5–3 7– 9 & 22–10	3.07 90.3	3.35 98.5
El Sad (Qaliub) ...	Maarad	Maize	24–2 24–9	3.66 79.5	4.39 95.5
*Sakha	Sakha 4	Rice	21–3 30–9 & 24–10	2.64 82.1	2.13 66.4
*Shubra el Sharkia	Sakel	Rice	6–3 24–9 & 16–10	2.69 76.7	2.69 76.7
*Abu Raqaba ...	Ashmouni ... Gedid ...	Berseem ... ... (c.c.)	2–3 29–8 & 30–10	6.35 88.7	7.57 103.4
*Motamadiya ...	Sakha 4	Rice	19–3 25–9 & 16–10	3.56 77.2	4.55 98.7
*Gimmeiza	Giza 7	Maize	8–3 18–9 & 22–10	4.83 78.9	6.22 101.7
*Qaha	Ashmouni ... Gedid	Maize	5–3 4–9 & ?	6.12 77.7	8.38 106.4

POTASH EXPERIMENTS.

Plot size: 1/40th FEDDAN.

the rate of 150 Kilos per feddan).

MENTS			Mean	S.E.	Yields
1½N+1½K	1½N+2P	1½ N+ 2P+1½ K			
8.81 96.1	9.93 108.3	9·22 100.5	9.17 100·0	0.28 3·06	In kantars per feddans. In per cent.
6.50 92.6	7.39 105.3	7.04 100.3	7.02 100.0	0.26 3.68	In kantars per feddan. In per cent.
6.86 96.0	7.82 109.4	7.21 101.0	7.15 100.0	0.26 3.59	In kantars per feddan. In per cent.
6.35 116.3	6.25 114.6	6.76 113.1	5.97 100.0	0.25 4.24	In kantars per feddan. In per cent.
3.68 108.3	3.33 97.8	3.58 105.2	3.40 100.0	0.10 3.05	In kantars per feddan. In per cent.
4.78 103.8	5.00 108.7	5.18 112.6	4.60 100.0	0.11 2.47	In kantars per faddan. In per cent.
1.98 61.6	4.44 138.2	4.88 151.6	3.22 100.0	0.26 7.94	In kantars per feddan In per cent.
3.15 89.7	4.57 130.03	4.44 126.2	3.51 100.0	0.16 4.48	In kantars per feddan. In per cent.
7.39 101.0	7.37 100.6	7.93 108.3	7.32 100.0	0.27 2.70	In kantars per feddan. In per cent.
4.78 103.4	5.03 109.2	5.13 111.9	4.61 100.0	0.25 5.40	In kantars per feddan. In per cent.
6.27 102.5	6.78 110.8	6.50 106.2	5.61 100.0	— —	In kantars per feddan In per cent.
8.56 108.7	8.66 110.0	7.65 97.1	7.87 100.0	— —	In kantars per feddan. In per cent.

TABLE 15. (*contd.*)—YEAR 193[illegible]

Layout: FIVE-SIDED LATIN SQUA[illegible]

($1\frac{1}{2}$ K means sulphate of potash at th

Locality	Variety	Previous crop	Dates of sowing and picking	TREA[illegible] No manure	$1\frac{1}{2}$ N
*Shokka	Giza 7	Berseem ...	4–3 6–10 & 17–10	1.85 84.9	2.36 108.8
*Siberbai	Sakha 4 ...	Berseem ... (c.c.)	25–2 5–9 & 14–10	5.64 91.4	6.26 99.2
*Siberbai (R.W.)	Ashmouni ... Gedid	Berseem ... ... (c.c.)	21–3 5–9 & 3–10	3.78 82.6	4.52 98.7
*Qimn el Arous	Ashmouni ... Gedid	Berseem ...	24–2 10–9 & 16–10	7.19 98.1	8.20 112.0
*El Azab	Ashmouni ... Gedid	Maize	25–2 29–8 & 18–9	7.06 83.5	8.38 98.8
*Kom Ombo	Giza 3	Maize	19–2 20–9 & 2–10	4.44 79.2	5.72 101.8
*Matâna	Giza 3	Maize	15–3 25–8 & 2–10	5.23 71.1	7.32 102.1
*Kufur	Ashmouni ... Gedid	Maize	15–3 15–9 & 13–10	6.30 83.2	7.82 103.4
*Sids	Giza 2	Wheat... ...	1–3 15–9 & 23–10	5.44 98.2	5.64 101.8
*Mallawi	Giza 19	Maize	21–2 15–9 & 11–10	7.75 88.3	9.09 103.6
*Tirsa (Giza) ...	Ashmouni ... Gedid	Tomatoes ...	7–3 5– 9 & 22–10	9.12 96.8	9.45 100.3

POTASH EXPERIMENTS

Plot size: 1/40th FEDDAN.

rate of 150 kilos per feddan)

MENTS			Mean	S.E,	Yields
$1\frac{1}{2}N+1\frac{1}{2}K$	$1\frac{1}{2}N+2P$	$1\frac{1}{2}N+2P+1\frac{1}{2}K$			
2.31	2.16	2.24	2.18	—	In kantars per feddan.
105.8	98.8	102.4	100.0	—	In per cent.
6.66	6.30	6.15	6.17	—	In kantars per feddan.
107.8	102.1	99.6	100.0	—	In per cent.
5.06	4.88	4.67	4.58	—	In kantars per faddan.
110.4	106.4	102.0	100.0	—	In per cent.
7.14	6.96	7.14	7.33	0.39	In kantars per feddan.
97.4	95.0	97.4	100.0	5.38	In per cent.
8.51	9.55	8.81	8.46	0.56	In kantars per feddan.
100.6	113.0	104.2	100.0	6.63	In per cent.
5.79	6.10	6.02	5.61	0.28	In kantars per feddan.
103.2	108.6	107.2	100.0	4.89	In per cent.
8.00	7.95	8.10	7.36	—	In kantars per feddan.
108.7	108.0	110.1	100.0	—	In per cent.
7.70	8.41	7.62	7.57	—	In kantars per feddan.
101.7	111.1	100.7	100.0	—	In per cent.
5.69	5.00	5.92	5.54	—	In kantars per faddan.
102.8	90.4	106.8	100.0	—	In per cent.
9.25	9.09	8.71	8.78	—	In kantars per feddan.
105.3	103.6	99.4	100.0	—	In per cent.
9.45	9.63	9.48	9.42	—	In kantars per feddan.
100.3	102.1	100.6	100.0	—	In per cent.

TABLE 16.—NITRATE AND SUPERPHOSPHATE EXPERIMENTS ON MAIZE 1932–1933. (Yields in Ardebs per feddan).

Lay out : SIX RANDOMISED BLOCKS WITH EIGHT TREATMENTS. *Plot size* : 1/40th FEDDAN.

Locality	Variety	Previous crop	Date of sowing	TREATMENTS								Mean	S.E.
				No manure	1 N	2 N	3 N	1N+2P	2N+2P	3N+2P	2 P		
Sibirbai	Baladi cross ...	—	1–8–32	3.87	4.71	6.20	8.77	4.52	6.81	8.27	3.47	5.83	0.43
Gimmeiza ...	Am. Early ...	Berseem	6–8–32	5.46	7.00	9.98	14.59	7.78	11.91	13.42	4.46	8.95	0.36
Defra	,, ...	Wheat	1–8–32	6.47	10.69	13.26	13.73	9.33	12.55	13.42	8.59	10.97	0.57
Kufur	,, ...	,, ...	5–8–32	8.18	10.29	11.59	12.31	10.94	11.44	11.87	9.14	10.72	0.59
*Hawaslia ...	,, ...	,, ...	15–8–32	9.67	9.42	9.59	9.36	9.26	9.14	9.54	9.70	9.46	0.62
*Mallawi ...	,, ...	Berseem	1–8–32	16.40	18.41	18.88	20.43	18.04	19.00	19.67	18.20	18.63	0.84
Matâna	,, ...	Wheat... ...	12–8–32	5.06	7.19	7.59	9.64	6.91	8.33	9.21	5.02	7.37	0.31
Sakha	,, ...	,, ...	30–7–33	4.00	7.07	9.58	11.07	7.16	9.14	11.73	4.37	8.02	0.42

Gimmeiza ...	,, ...	Berseem ...	22–7–33	14.26	14.29	16.31	15.50	15.76	17.67	16.74	13.15	15.46	0.86
Defra	,, ...	Wheat	22–7–33	8.06	11.97	14.54	15.50	11.09	15.50	16.40	7.69	12.59	0.42
Sids	,, ...	Berseem	21–7–33	7.41	10.39	12.99	13.61	9.46	11.50	13.61	9.74	11.09	0.45
Hawaslia... ...	,, ...	Wheat	13–8–33	3.75	9.45	12.93	13.51	9.48	12.80	14.01	4.40	10.04	0.67
Mallawi	,, ...	Berseem	3–8–33	16.49	19.32	19.72	19.00	18.91	19.50	19.19	17.83	18.75	0.56
*Matâna	,, ...	,, ...	10–8–33	6.00	7.28	7.07	7.81	7.22	8.90	7.56	6.97	7.35	0.60

TABLE 17.—VARIETY AND MANURING EXPERIMENTS WITH MAIZE 1933. (Yields in Ardebs per feddan)

Locality	Previous crop	Date of sowing	TREATMENTS						Mean	S. E.
			No manure		$1\frac{1}{2}$ N		3 N			
			Am. Early	Balady	Am. Early	Balady	Am. Early	Balady		
Sakha	Wheat	30–7	3.25	4.46	9.16	8.18	12.09	9.44	7.77	0.72
Gimmeiza	Berseem	11–8	9.67	8.98	10.74	12.23	12.28	12.32	11.04	0.83
Talkha	,, ...	17–8	5.58	3.09	9.44	4.93	10.83	5.58	6.71	0.29
Dekernis	,, ...	24–8	4.55	3.30	5.95	4.37	7.30	5.72	5.20	0.18
Mit Gaber	Wheat	3–8	3.81	4.37	9.90	9.30	14.23	14.37	9.34	0.33
Qaha	,, ...	27–7	8.32	6.88	15.67	12.00	16.13	14.04	12.18	0.41
Defra	,, ...	26–7	11.02	9.16	14.23	11.76	15.25	13.06	12.42	0.38
Ashmoun	,, ...	8–8	3.16	3.67	8.46	9.76	13.06	13.25	8.56	0.33

Matania	Berseem	30–7	14.69	11.76	17.67	15.53	18.65	17.02	15.90	0.50
Tarfaya	Wheat	2–8	10.55	9.86	14.74	13.39	14.88	13.30	12.79	0.81
El Azab	Berseem	29–7	6.18	7.35	11.86	10.93	13.25	11.39	10.17	0.43
Sids	,, ...	31–7	7.12	5.44	10.46	8.14	12.04	10.70	8.99	0.43
Hawaslia	Wheat	13–8	2.23	3.67	8.23	8.18	12.23	12.32	7.81	0.85
Mallawi	Berseem	2–8	16.46	14.46	19.86	17.25	19.95	17.21	17.54	0.75
Matâna	,, ...	9–8	5.90	5.48	7.48	8.74	7.67	8.14	7.24	0.63

3

EXTRAIT DU BULLETIN DE L'UNION DES AGRICULTEURS D'EGYPTE.
37ème Année, Mars 1939, No. 301.

Les effets du sol, de la saison et de la fumure sur la végétation et le rendement du cotonnier.

Les quelques pages qui suivent contiennent la traduction *in extenso* d'une conférence faite par M. D.S. Gracie de la Section Chimique du Ministère de l'Agriculture, devant les membres de « The Real Estate Association for Egypt », à Alexandrie le 14 Mars 1939.

Nous sommes sûrs que les lecteurs du Bulletin liront avec plaisir et intérêt l'interprétation des très nombreux résultats des expériences effectuées sous la direction du savant conférencier.

En quelques mots d'introduction, le Dr. W.L. Balls signale l'écourtement de la période de végétation du cotonnier dû à des facteurs divers: climat, espacement, date d'ensemencement, variétés. D'après les données relevées par l'office météorologique du Département Physique d'Egypte, la température moyenne en Egypte, en même temps que celle de l'Europe Orientale, s'est élevée d'un degré centigrade au cours de ces dernières vingt cinq années. Cette élévation si minime qu'elle paraisse, a influencé d'une façon considérable la végétation du cotonnier en l'accélérant. En outre, de par la réduction de l'espacement des plantes, on est arrivé à obtenir une plus forte récolte en provoquant l'apparition d'un plus grand nombre de capsules précoces qui échappent de ce fait aux attaques du ver rose de la capsule.

Ainsi donc, la saison de végétation du cotonnier s'est trouvée écourtée de deux mois par les contre-mesures d'espacement prises contre le ver rose et en outre d'une quinzaine de jours à peu près, grâce à un changement de climat, qui échappe au contrôle de l'homme.

Dans sa conférence, M. Gracie a résumé et commenté les résultats d'expériences sur la fumure du cotonnier qui ont été effectuées pendant huit années consécutives dans de nombreuses localités différentes de l'Egypte. Le nombre d'expériences depuis 1931 fut en moyenne de trente par année; on a ainsi recueilli les résultats d'environ deux cent quarante expériences.

Au moyen de l'analyse statistique des résultats, M. Gracie a établi les corrélations existant entre le rendement et la fumure du cotonnier en tenant compte aussi d'autres facteurs tels que les conditions climatériques, les conditions physico-chimiques du sol, la date des semailles, les dates d'irrigation et aussi, en dernier lieu, du nouveau mode d'ensemencement au plantoir (dibble sowing) qui semble avoir donné des résultats très encourageants.

Tous ces facteurs interviennent au cours de la végétation du cotonnier, en commençant par l'état physico-chimique du sol (conditionné par le drainage) dont dépend l'absorption normale de l'eau d'irrigation par les plantes; la température pendant les mois de Mars et d'Avril qui suivent les semailles dont dépend le premier développement de la plante et la floraison normale; la température pendant Juillet et Août dont dépend la maturité des capsules tardives et enfin l'action de la fumure azotée qui dépend de tous les facteurs à la fois. On peut en conclure que la fumure azotée produit son maximum d'effet quand tous ces facteurs réunis sont favorables à l'obtention d'une bonne récolte sur une bonne terre normale. Quand l'un ou plusieurs de ces facteurs sont défavorables et que le rendement général est bas la fumure azotée demeure inefficace, quelle que soit la quantité d'engrais employée.

Des nombreux facteurs énumérés ci-dessus, les plus importants sont incontestablement les propriétés physico-chimiques du sol conjointement avec les conditions atmosphériques. Ce sont généralement deux facteurs adverses qui coopèrent pour provoquer un déclin sensible du rendement.

R. ALADJEM.

Le temps et la récolte, 1905 à 1938. —

L'existence d'effets saisonniers sur la récolte du coton en Egypte est devenu depuis quelques années, de plus en plus apparente. Cela est dû en partie à la précision croissante de notre technique dans l'enregistrement et l'étude de la récolte cotonnière. Cela est dû aussi à ce que nous venons justement d'avoir deux saisons qui représentent presque le mieux et le pire de l'effet sur le coton des variations saisonnières du climat égyptien. On peut le démontrer grâce aux données recueillies par notre section botanique pour les mêmes dix-huit endroits dans ces deux années, représentant pour chaque endroit le comportement moyen de plusieurs variétés sous essai. Ces endroits sont représentatifs de la bonne culture ordinaire du district mais sont surveillés avec un soin particulier et sont pour ainsi dire exempts de dégâts causés par le ver du coton.

Le temps, en 1937 avait été tel que, particulièrement dans le Delta, les fleurs et les capsules furent très précoces, la capsulaison atteignit la maximum et le rendement fut très élevé, tandis qu'en 1938 la croissance fut tardive, ne s'éleva guère jamais très haut et le rendement fut mince, dont nous devons déduire encore un peu moins d'un million de cantars du fait des dégâts causés par le ver du coton. D'ailleurs cette activité accrue du ver du coton était elle-même une conséquence des conditions météorologiques. Dans ces deux années la récolte égyptienne fut donc dominée par des causes naturelles qu'aucune mesure humaine, législative ou administrative, n'était à même de modifier.

Ces deux récoltes anormales ont malheureusement causé beaucoup de confusion dans les idées. Une dépression dans les prix du coton survint il y a deux ans, mais la forte récolte de 1937 maintint le revenu en argent par feddan des propriétaires fonciers presque au même niveau qu'en 1936. Quand arriva la faible récolte de 1938 avec les mêmes prix, la dépression en dollars par feddan fut sérieuse, mais au lieu de reconnaître simplement la malchance d'un climat incontrôlable, nos journaux étaient remplis de vains propos sur la chute récente du prix du coton, alors qu'en réalité il n'y en avait pas eu pendant ces deux dernières années, si bas qu'eussent été les prix.

Tenter une analyse de la façon dont les conditions météorologiques contrôlent la récolte, au delà de tout secours humain, serait trop technique. Nous pouvons grosso-modo résumer ainsi l'idéal : un sol chaud au printemps, pas de khamsin et un été frais et sec. L'inverse est abominable.

Mais au temps de l'avant-guerre nous avions coutume de penser que le plus grand atout de l'Egypte c'était la régularité de ses saisons de sorte que nous pouvions toujours compter sur la production d'une récolte de même importance tous les ans, à l'exception des années de mauvaise crue. Pourquoi à présent cette variabilité ? Le climat s'est-il déréglé ? Une comparaison du temps et du pourcentage de production des capsules par feddan à Guizeh avant la guerre et tout récemment donne immédiatement la réponse. La saison pendant laquelle nous pouvons cultiver le coton a été écourtée de plus de deux mois par le ver rose de la capsule, et il y a plus de chances, dans une période tellement plus courte que la moyenne météorologique subisse des variations plus prononcées que dans une période plus longue.

Nous avons réussi à revenir à l'ancien niveau de récolte en recourant à un espacement plus serré et en obtenant ainsi, une récolte plus grande de capsules précoces avant que l'attaque du ver rose soit sérieuse, bien que le pays en général ne se soit pas encore très avancé dans cette voie. Nous ne pouvons d'ailleurs pas le faire complètement parce qu'un billonage étroit au point de devenir impraticable, serait nécessaire pour avoir un nombre de plantes par feddan, quatre fois plus grand qu'avant-guerre. Cette densité quadruple est l'optimum moderne qui peut s'obtenir avec le semis au plantoir ; avec le semis ordinaire, on peut obtenir une densité triple.

Mais bien que ces faits nous soient familiers depuis de nombreuses années, nous avons subi comme un choc quand, pour la première fois il y a quelques semaines, nous avons jeté les yeux sur un diagramme où étaient rapprochées les courbes de capsulaison d'avant et d'après-guerre.

Non seulement la courbe de capsulaison moderne est brutale, haute et courte en comparaison de l'ancienne lente et douce, mais elle est encore décalée de dix jours en avance. Ainsi, la cueillette entière est déjà terminée à un moment où nous ne pensions qu'à la commencer en 1912 et 1913.

Ce décalage dans le temps est réel. A Guizeh, de 1905 à 1914 je n'avais jamais constaté l'apparition d'une seule fleur avant le 1er Juin ; actuellement nous en trouvons dès le 20 Mai, presque chaque année. Il est prouvé que ce n'est pas dû à l'espacement plus serré ; il est prouvé aussi que ce n'est pas dû à la date de l'ensemencement. Ce pourrait être dû en partie à l'irrigation commencée plus tôt pour conserver les boutons précoces, mais le fait était évident, lorsque je suis revenu ici, en 1927, avant que l'ancienne ordonnance des arrosages eut été modifiée. Il se peut que ce soit dû au changement des variétés ; mais l'Assili était considéré comme une variété précoce avant la guerre tandis que le Sakha 4 n'est pas une des plus précoces d'aujourd'hui, et cependant la différence de 10 jours s'applique aussi entre ces deux variétés. Une explication plausible est révélée par les données de l'office météorologique du Département de Physique, à savoir que la température moyenne de l'Egypte s'est élevée (en même temps que celle de l'Europe Orientale) d'un degré centigrade depuis l'avant-guerre. C'est un changement de climat très lent et par conséquent il a dû inévitablement avoir élevé la température maximum du sol d'au moins autant.

Un degré semble bien peu de chose, mais c'est beaucoup pour les racines des plantes, son action effective étant proportionnelle à la cinquième puissance, au moins, de la valeur d'un tel changement.

Deux degrés à la profondeur d'un mètre représentant la différence de la température du sol d'une mauvaise et froide saison de semaille et d'une bonne et chaude.

Ce changement de climat explique pourquoi nous semons aujourd'hui beaucoup plus tôt que la date optimum qui avait été avant-guerre.

Ainsi donc, notre saison cotonnière a non seulement été raccourcie de deux mois par les mesures concernant l'espacement prises pour lutter contre le ver rose de la capsule mais encore de presque un demi mois supplémentaire par un changement climatérique qui est entièrement hors du contrôle humain. Par conséquent, les variations saisonnières auparavant négligeables sont maintenant devenues d'une importance bien définie et peuvent être relevées à chaque pas dans les résultats de M. Gracie, bien qu'elles ne soient pas aussi grandes que dans des pays moins favorisés.

Enfin, que des plaintes amères se feront entendre dans l'avenir, quand la température tendra de nouveau à baisser, que la culture deviendra plus tardive, et qu'on rendra le Ministère de l'Agriculture responsable des actes de la divinité.

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La thèse principale développée dans une conférence précédente sur ce sujet devant cette Association, c'était que l'effet des engrais azotés était « secondaire » sur le rendement du coton en Egypte et qu'il ne pouvait varier que dans les limites imposées par les facteurs « primordiaux » du niveau de rendement.

Le manque d'azote assimilable dans le sol était rarement assez grand pour constituer un facteur limitatif (limiting factor) effectif de la récolte. Nous avions démontré aussi que ceci ne signifiait pas que les engrais azotés ne pouvaient pas exercer une influence importante sur le rendement mais qu'ils ne pouvaient le faire que si le rendement était déjà élevé et dans des saisons favorables. Les facteurs d'importance primordiale étaient le degré d'assoiffement tel qu'il est conditionné par les propriétés physico-chimiques du sol conjointement avec le climat, la date de l'ensemencement, l'espacement et la variété, ce à quoi nous ajouterons maintenant le mode d'ensemencement. Cette conférence va encore développer et amplifier cette thèse et grâce à la plus grande gamme de résultats dont nous disposons maintenant il devient visible en particulier qu'on n'accordait pas assez d'attention à l'influence des conditions climatériques pendant la première partie de la saison de végétation.

Principes de l'expérimentation. —

La base des connaissances quant à l'effet des engrais sur le cotonnier en Egypte est constituée par la série d'expériences exécutées annuellement sous la direction de la section agronomique du Ministère de l'Agriculture. La plus grande chance d'erreur réside dans l'influence de la localité, et l'idée maîtresse de ces expériences est qu'en n'importe quelle année, elles soient suffisamment nombreuses et bien distribuées dans tout le pays pour que les résultats en soient susceptibles d'être soumis à l'analyse statistique et applicables à la culture du coton dans le territoire égyptien pris dans son ensemble. Nous devons insister ici sur le fait que les informations présentées ici n'auraient pas pu être obtenues autrement. Nous attachons autant d'importance, sinon plus, au nombre d'observations qu'à la précision de l'expérience individuelle tout en ne négligeant pas cet aspect de la question. Le dispositif adopté pour chaque expérience individuelle est tel que l'analyse statistique des rendements des parcelles donne une estimation valable de l'erreur et peut révéler si oui ou non les traitements ont exercé un effet notable (significatif) sur un sol donné. La seule variante dans l'expérience est l'engrais fourni tandis que les facteurs sol, date de semailles, etc..., varieront d'une expérience à l'autre et le facteur climat d'une année à l'autre. L'expérimentation sur cette échelle se poursuit depuis 1931 et comme le nombre d'expériences s'élève « grosso modo » à 31 par année, on dispose des résultats d'un nombre d'expériences s'élevant approximativement à deux cent quarante. Dans les expériences de 1936 et 1937 le coton fut semé au plantoir (« dibble sowing ») et dans celles de 1938 on a modifié le plan pour permettre la comparaison directe entre l'effet de la fumure sur le coton semé au plantoir et celui semé selon la méthode ordinaire.

A partir de 1935 on a prélevé des échantillons de terre se rapportant à toutes les expériences et les chiffres fournis par les analyses dont ils ont été l'objet au laboratoire sont utilisés pour des comparaisons avec les rendements enregistrés.

Interprétation des résultats. —

L'interprétation de l'effet des traitements (dans ces expériences de fumure) dépend dans une très large mesure des chiffres relatifs à la proportion de la récolte obtenue dans la seconde cueillette.

C'est seulement quand les excédents de récolte résultant d'un traitement correspondent à la « diminution » d'importance de la seconde cueillette, c'est-à-dire à une augmentation des capsules précoces, que le facteur impliqué peut être considéré comme ayant été le facteur limitatif (limiting factor) de la récolte.

Cet effet se distinguera nettement du cas opposé où l'effet du traitement se traduit par une « augmentation » dans le pourcentage de la seconde cueillette. Des augmentations importantes de rendement peuvent, bien entendu, aller de pair avec une augmentation dans le nombre de capsules tardives mais, dans ce cas, il est évident qu'il y a un élément beaucoup plus grand d'incertitude.

Il peut arriver aussi que la proportion de la récolte obtenue dans la seconde cueillette soit augmentée d'une façon significative (susceptible d'une interprétation) par une application d'azote par exemple (ce qui démontre que la plante en a absorbé plus ou moins) sans qu'il y ait cependant un effet significatif sur le rendement total.

Effets de l'apport d'azote sur la moyenne des rendements. — Le tableau suivant donne la moyenne des rendements des parcelles témoins et la moyenne des excédents par rapport aux témoins pour chaque niveau d'azote et pour chacune des années sous revue (cantars par feddan) :

TABLEAU I.

Année	Rendement moyen des parcelles témoins	O — 1N	O — 2N	O — 3N	O — 4N
1931	4.64	0.53	0.74	0.86	—
1932	4.83	0.71	1.08	1.39	—
1933	5.25	0.73	1.22	1.58	—
1934	5.00	0.74	1.12	1.46	1.72
1935	6.09	0.80	1.30	1.57	1.63
1936	5.75	0.75	1.37	1.80	2.00
1937	6.98	1.07	1.92	2.34	2.62
1938	5.49	0.65	1.04	1.14	1.13
Moyenne	5.50	0.75	1.22	1.52	1.82

N.B. — 1N signifie l'application d'un engrais azoté donnant 15 1/2 kgs. d'azote par feddan.

On peut déduire de ce tableau que l'effet produit par l'application d'un engrais azoté varie énormément d'une année à l'autre.

Les années 1937 et 1938 contrastent violemment en ce sens que l'azote ajouté se montra d'une efficacité double la première année que la deuxième (trois sacs de nitrate par feddan donnèrent une augmentation de 2.34 kantars en moyenne par feddan en 1937 contre 1.14 kantars en 1938).

Les chiffres moyens correspondants aux variations du pourcentage de la récolte représenté par la seconde cueillette en passant d'un niveau d'azote à l'autre, sont donnés dans le tableau suivant, c'est-à-dire les augmentations moyennes totales du pourcentage de la récolte obtenu à la seconde cueillette en allant de :

TABLEAU II.

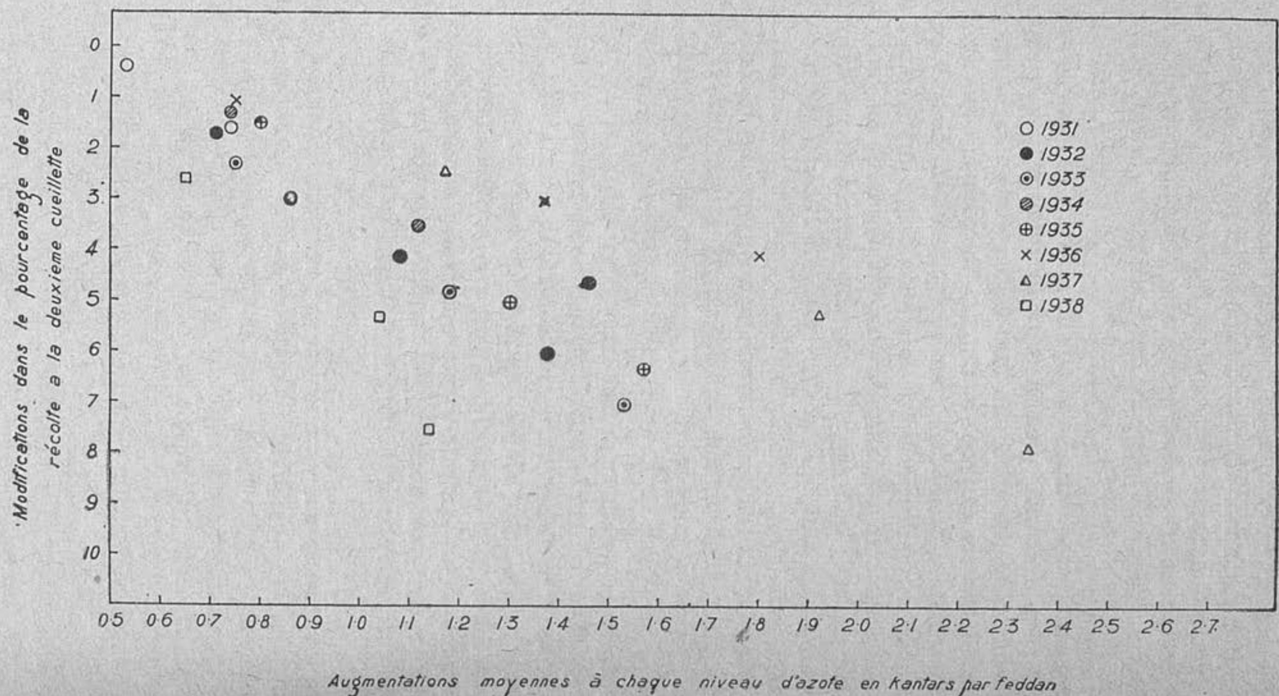
Année	O-1N	O-2N	O-3N	O-4N
1931	0.4	1.6	3.0	—
1932	1.7	4.1	6.0	—
1933	2.3	4.8	7.0	—
1934	1.3	3.5	4.6	7.2
1935	1.5	5.0	6.2	8.3
1936	1.1	3.0	4.4	6.0
1937	2.4	5.2	7.8	9.6
1938	2.6	5.3	7.5	8.7

Si on compare dans un diagramme (pg. 158) l'augmentation de rendement correspondant aux différents niveaux d'azote donnée dans le Tableau I avec l'augmentation du pourcentage de la seconde cueillette dans la récolte on voit tout de suite que les effets sur le rendement provoqués par l'apport d'azote dépendent très étroitement du nombre des capsules tardives cueillies, mais dans une mesure qui varie avec chaque saison. On pourra observer que les points pour les années 1931/32, 1933 et 1935 tombent sur une même ligne droite, ceux pour 1936 et 1937 (et dans une moindre mesure pour 1934) sont significativement plus élevés que cette ligne, tandis que ceux pour 1938 occupent une position significativement inférieure. Ce diagramme met en évidence deux effets : le prolongement d'une ligne de points reflète l'abondance des capsules tardives cueillies tandis que la position qu'occupe la ligne dépend, ainsi qu'il sera démontré, de la mesure dans laquelle l'engrais azoté a été capable d'affecter les capsules précoces.

Influence de la date des semailles et de la saison. —

Ces variations saisonnières des effets produits par l'apport d'azote doivent, en grande partie, être attribuées à des différences dans les conditions climatériques. On peut peut-être apprécier au mieux, ici la nature des variations en prenant en considération les variations constatées en rapprochant d'une part la date des semailles et le rendement des parcelles témoins et de l'autre la date des semailles et l'effet dû à l'apport d'azote dans chacune des huit années d'expé-

RAPPORT ENTRE LES EFFETS DE LA FUMURE SUR LE RENDEMENT
ET L'AUGMENTATION DE LA PROPORTION DE LA REÇOLTE
A LA DEUXIEME CUEILLETTE



rience. (En général, d'ailleurs, plus la date des semailles est tardive moins élevé est le rendement des parcelles témoins et la réaction à l'engrais moins prononcée).

Il y a presque toujours une relation mais l'importance en varie avec la saison et la localité. La relation entre le date des semailles et le rendement des parcelles témoins fut très significative en 1933 et 1938 tandis que celle entre la date des semailles et les augmentations maxima dues à la fumure azotée ne le fut qu'en 1936 et 1937. Au cours de chacune de ces quatre années il est à remarquer que la relation devient moins marquée quand on fait entrer en ligne de compte les expériences effectuées en Haute-Egypte.

Il était donc possible en 1936 et 1937 d'augmenter de façon marquée la production de capsules « précoces » du coton semé tôt dans le Delta par des applications d'engrais azotés. On doit noter que les effets sur le rendement peuvent être très grands. Les chiffres moyens données dans le Tableau I des augmentations dues à l'apport d'azote en 1937 vont depuis plus de quatre cantars pour des semailles effectuées le 19 Février jusqu'à la moitié de cette quantité pour des semailles effectuées le 17 Mars, les deux essais ayant été faits dans le Delta avec la variété Guizeh 7.

Un des traits les plus frappants de ces expériences, exception faite pour les années 1936 et 1937, c'est que lorsque pour n'importe laquelle des variétés on établit un diagramme comparant les rendements et les traitements à l'aide desquels ils ont été obtenus, il en résulte une série de lignes parallèles. Ce parallélisme signifie que dans ces années prédominaient des facteurs tels que l'assoiffement conditionnés par les propriétés physico-chimiques du sol et que l'engrais ne jouait qu'un rôle secondaire. D'un autre côté, si en 1936 et 1937 il existe encore un parallélisme analogue dans les expériences où les semailles ont été tardives, les lignes relatives au coton semé tôt croisent toutes les autres, c'est-à-dire que pour ces deux années les semailles hâtives et la fumure pouvaient nous permettre dans une certaine mesure de ne pas tenir compte du rôle joué par les propriétés physico-chimiques du sol.

Le facteur qui provoque toutes ces variations saisonnières dans le comportement des plantes doit être constitué principalement par la température qu'elles subissent au cours de la période de croissance. Les moyennes mensuelles de températures maxima aux mois de Mars et de Juillet dans trois stations du Delta pour les huit années sous revue sont les suivantes :

VARIATION SAISONNIÈRE DE L'INFLUENCE DE LA DATE D'ENSEMENCEMENT SUR LE RENDEMENT DES PARCELLES TEMOINS ET SUR L'AUGMENTATION DE LA RECOLTE DUE A L'AZOTE

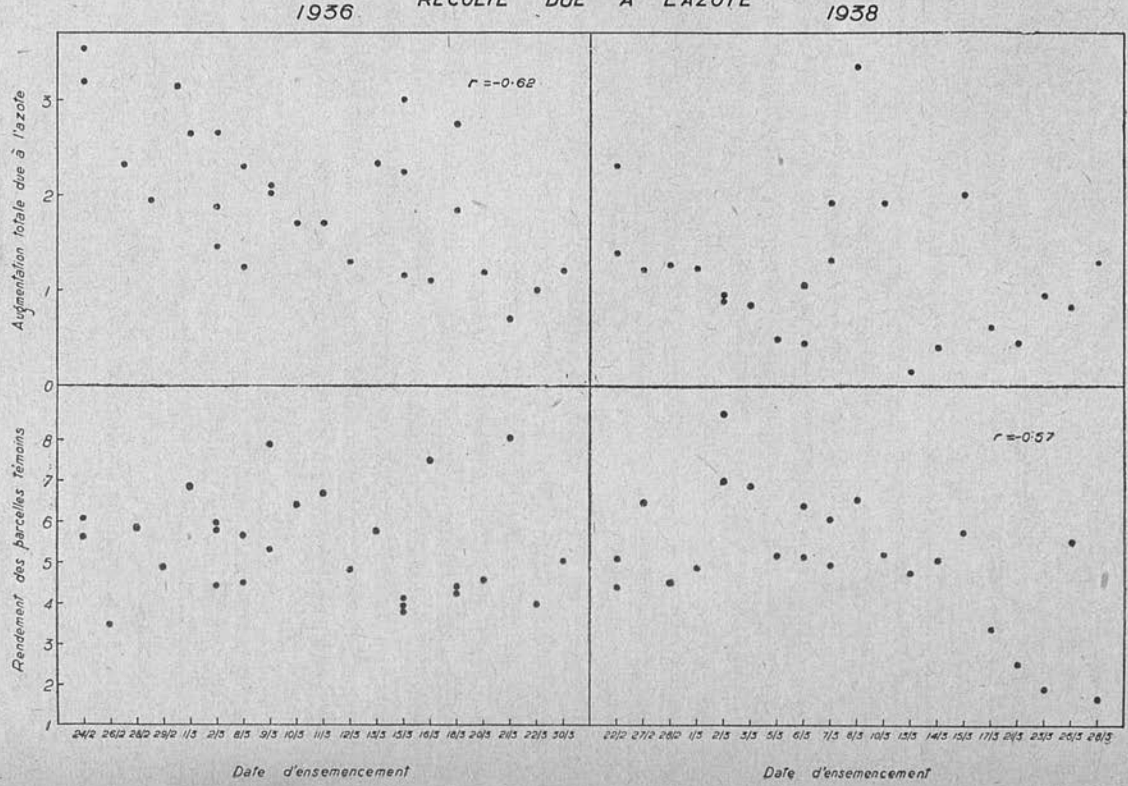


TABLEAU III.

	1931	1932	1933	1934	1935	1936	1937	1938
Mars	26.3	24.8	23.5	25.1	24.5	25.1	25.5	21.5
Juillet	36.2	36.6	33.6	34.8	34.3	35.5	35.0	35.6

Il ressort de ce tableau que lorsque les moyennes mensuelles de températures maxima pour Mars sont basses la correspondance entre la date des semailles et le rendement des parcelles témoins est grande mais lorsque la température est élevée, c'est la correspondance entre la date des semailles et l'augmentation de rendement due à la fumure azotée qui devient marquée.

De par les courbes de floraison et de capsulaison pour 1937 et 1938 déjà présentées par le Dr. Lawrence Balls, on peut se rendre compte que la température pendant la première partie de la saison de croissance doit être considérée comme d'importance primordiale, que ce soit en Haute ou en Basse-Egypte. La correspondance est moins marquée ou inexistante en Haute-Egypte parce que les conditions climatériques y permettent généralement des semailles hâtives et, comme on le verra plus loin, il y a probablement moins d'effet de la fumure azotée sur les capsules précoces du fait de l'assimilabilité plus grande là que dans le Delta, de l'azote déjà présent dans le sol. La date optimum des semailles dans le Delta, dans une quelconque des localités, doit d'autre part varier d'année en année suivant la température. Des essais sur la date des semailles du Dr. Balls il est possible de déduire que par un printemps froid, les semailles optimales soient les semailles « tardives » dans le Nord du Delta plutôt que plus au Sud, tandis que par un printemps chaud, les semailles les plus hâtives possibles seraient préférables partout. La restriction absolue imposée à la croissance dans le premier cas limite les possibilités de la fumure tandis que, dans le deuxième cas, les conditions plus favorables permettent à la fumure azotée d'exercer une action stimulante sur la production de capsules précoces. Et l'importance de cette stimulation correspondra exactement à la mesure dans laquelle on aura tiré profit de ces conditions plus favorables, ce que démontrera la date des semailles.

Ces expériences sur la date des semailles suggère aussi (ce qui est intéressant) que la saison de croissance étant plus courte aujourd'hui qu'il y a 25 ans, la culture du coton est devenue beaucoup plus sensible aux conditions climatériques, le temps étant moindre pour que des effets compensateurs puissent se produire.

Les autres effets principaux sur le rendement de la fumure azotée dans ces expériences dépendent de jusqu'à quel point il est possible de cueillir les « capsules tardives », ce qui ressort de l'augmentation du pourcentage de la récolte obtenu à la seconde cueillette.

Si les chiffres des moyennes dans le Tableau II et l'augmentation de ce pourcentage provoquée par l'application de trois sacs de nitrate sont comparés avec les moyennes mensuelles de température maxima correspondantes pour Juillet, il devient évident qu'il y a une corrélation inverse, c'est-à-dire qu'un temps très chaud en Juillet provoque une chute excessive de capsules tardives. La chute excessive de capsules pendant les étés exceptionnellement chauds tend, de plus, à être aggravée par suite d'une attaque plus forte du ver rose de la capsule. La différence sérieuse dans l'action de la fumure azotée en 1936 et en 1937, les deux années dans lesquelles l'engrais pouvait influencer la production des capsules hâtives dans le Delta, réside en ce qu'à cause du temps plus chaud en Juillet, on ne put récolter qu'un plus petit nombre de capsules tardives la première année. En admettant que l'action de la fumure azotée dépende principalement de la cueillette des capsules tardives, il n'en est pas moins vrai qu'en considérant l'ensemble des essais, l'emploi de plus d'un sac est une pure spéculation quant à ce que seront les conditions climatériques pendant l'arrière-saison.

L'interprétation de ces effets saisonniers au moyen des températures moyennes maxima de Mars et Juillet n'est, nous l'admettons, que simplement approximative. Pour les interpréter pleinement, les conditions climatériques de la saison entière de croissance allant de Février à Septembre devraient, de toute évidence, être prises en considération. Ainsi en 1931 où la température fut la plus favorable en Mars de toutes les huit années, les mois d'Avril, Mai et Juin furent favorables mais pour être suivis après, en Juillet, Août et Septembre par les températures moyennes les plus élevées d'aucune de ces années. En cette année-là des plantes exceptionnellement bien développées souffrirent donc d'une sécheresse exceptionnellement rigoureuse et le résultat en fut qu'on ne put cueillir pour ainsi dire pas de capsules tardives et qu'on obtint les rendements les plus faibles de tous avec la fumure azotée.

Il se peut que tout ce qui vient d'être dit on le doive justifier pour une année moyenne par un facteur que nous allons discuter maintenant. Dans les expériences de fumure de 1936 et 1937 le coton fut pour la première fois semé au plantoir (« dibble sowing »). Puisque le bénéfice du semis au plantoir provient des capsules précoces il devient évidemment possible que la corrélation entre la date des semailles et l'action de l'azote constatée pendant ces deux années peut n'être pas due seulement aux conditions favorables en Mars mais à l'action combinée des trois facteurs : la date des semailles, la température et la « méthode d'ensemencement ». Le dispositif des expériences de 1938 fut modifié en conséquence pour permettre la comparaison directe des effets de la fumure sur coton semé au plantoir et sur celui semé suivant la méthode ordinaire. C'était une entreprise ambitieuse puisqu'on se trouvait ainsi en présence d'une expérience à facteur multiple sur une grande échelle. L'entreprise, cependant fut menée à bonne fin. (Chaque expérience comprenait 120 parcelles et occupait trois feddans).

Méthode de semis. —

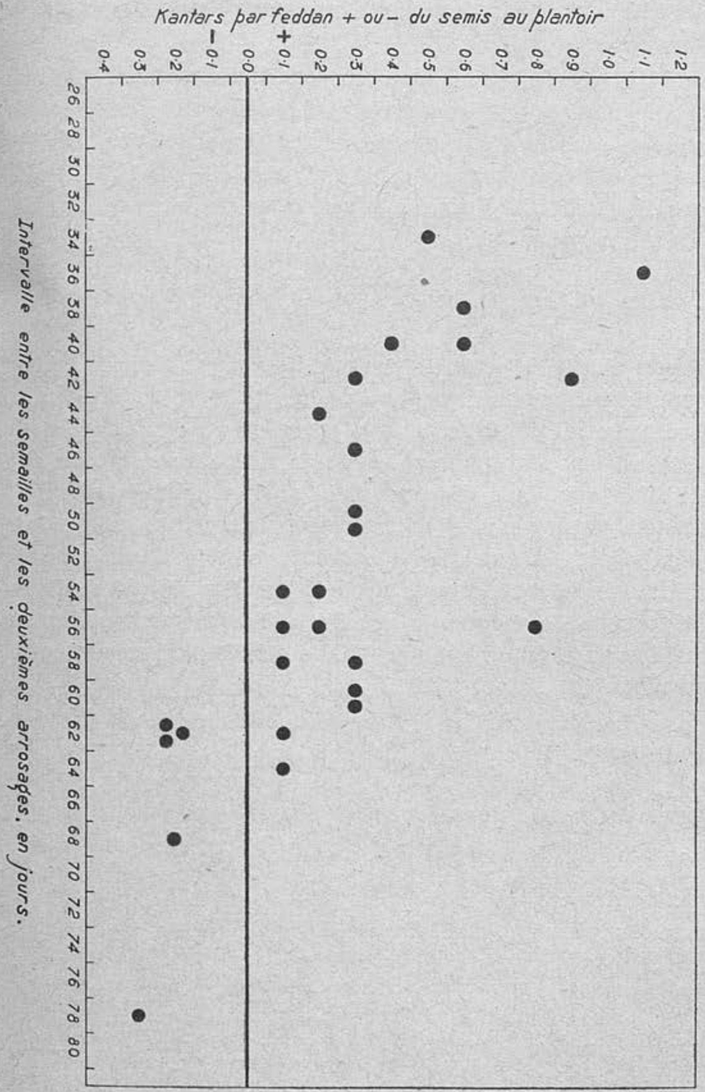
Il y eut en tout trente et une expériences en 1938.

L'analyse statistique des résultats montre que dans quinze d'entre elles il y eut un effet positif significatif sur le rendement du coton semé au plantoir ; dans trois, il y eut un effet déprimant significatif ; dans douze il n'y eut aucun effet notable ni dans un sens ni dans l'autre et dans l'expérience restante, bien qu'il n'y eût pas d'effet direct signiicatif de la méthode de semis, il y eut cependant une réaction significative entre la fumure azotée et le mode d'ensemencement. Cette série de résultats semblait bien confuse jusqu'à ce que nous eûmes comparé l'augmentation et la diminution du rendement occasionnées par le mode d'ensemencement à l'intervalle (en journées) entre les semailles et les premiers arrosages et à l'intervalle total entre les semailles et les deuxièmes arrosages. La corrélation dans le premier cas se traduit par $r = -0{,}67$ et dans le second cas par $r = -0{,}75$ de sorte que quoique le premier intervalle soit le plus important, celui entre les premiers et les seconds arrosages a aussi quelque influence.

Si on pratique l'ensemencement au plantoir il est encore plus important que les plantes les meilleures obtenues par cette méthode ne soient pas assujetties à l'assoiffement. L'effet positif moyen sur le rendement des parcelles semées au plantoir de toutes les trente et une expériences était de 0.24 cantars par feddan et s'éleva à 0.51 cantars dans les cas des 15 expériences où l'on constata une différence positive significative.

Ce dernier chiffre est une sous-estimation de ce qui était possible, parce que même dans ces quinze expériences la fourniture d'eau n'était pas nécessairement en quantité optimum.

L'ASSOIFFEMENT ET LE SEMIS AU PLANTOIR
(DIBBLE SOWING)



L'augmentation du rendement grâce à l'ensemencement au plantoir s'accompagne d'une proportion « réduite » de la récolte à la deuxième cueillette c'est-à-dire que cette augmentation se porte sur les capsules précoces.

Les profits directs en rendement que rendent possibles et l'ensemencement au plantoir et la réduction des intervalles entre les premiers arrosages avaient été, naturellement, démontrées il y a plusieurs années par des expériences de la Section Botanique. L'intérêt ici réside dans la possibilité d'une interaction entre le mode d'ensemencement et la fumure azotée.

Interaction entre la fumure azotée et le mode d'ensemencement. —

Il est regrettable à ce point de vue que la comparaison de l'effet des engrais sur le coton semé au plantoir et sur le coton semé par la méthode ordinaire ait été faite pour la première fois en une saison de végétation aussi peu favorable que celle de 1938. L'interaction ne devint significative que dans un très petit nombre d'expériences et dans ce petit nombre même il y a des raisons de croire qu'elle fut le résultat d'un autre facteur. L'importance possible d'une grande interaction dans une saison normale ne doit pas être éliminée, d'autant plus que, comme l'a montré le Dr. Balls, l'écartement optimum dans les semailles au plantoir est plus faible que dans le mode ordinaire d'ensemencement.

La nature d'une interaction de ce genre ressort clairement des moyennes suivantes :

Augmentations du rendement (cantars par feddan). —

	O-1N	O-2N	O-3N	O-4N
		Pour toutes les expériences		
Ensemencement ordinaire	0.69	1.00	1.10	1.12
Ensemencement au plantoir	0.64	1.06	1.19	1.20
	Pour les quinze expériences montrant une différence positive significative en faveur de la méthode au plantoir			
Ensemencement ordinaire	0.76	1.15	1.19	1.24
Ensemencement au plantoir	0.82	1.25	1.37	1.45

On assurera d'autant plus le succès de la fumure azotée qu'on améliorera les conditions soit en laissant des intervalles plus convenables entre les arrosages, soit en semant au plantoir soit encore par les deux à la fois.

Ceci doit être considéré comme mettant bien en lumière le principe général déjà fixé pour la fumure du coton : à savoir que l'effet des engrais azotés est d'autant plus grand que le rendement est plus élevé.

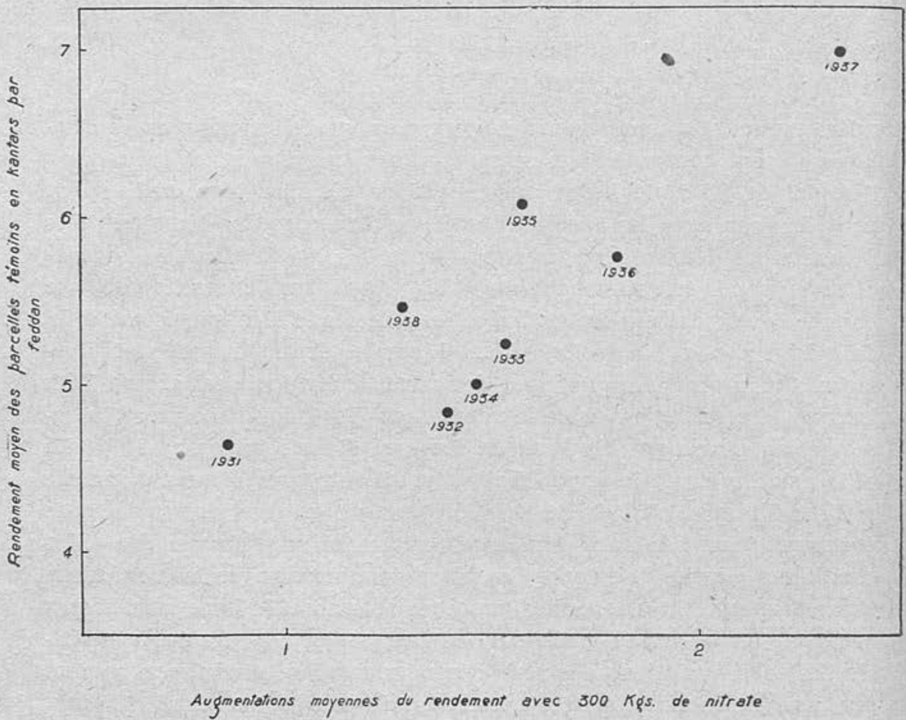
Le rendement et l'effet de l'azote. —

Le principe général énoncé ci-dessus est le mieux mis en lumière quand les rendements moyens des parcelles témoins du Tableau I sont comparés aux augmentations moyennes obtenues par l'emploi de 3N ; de fortes augmentations résultant des engrais qui vont de pair avec les rendements élevés des parcelles témoins. Les facteurs qui déterminent les rendements des témoins sont : les conditions du sol conjointement avec les conditions climatériques, de bonnes façons culturales, les irrigations, le mode d'ensemencement, la date des semailles, la variété, etc... L'année pendant laquelle la corrélation fut la plus marquée pour des essais individuels est encore 1933, lorsque la corrélation entre le rendement élevé des témoins et l'augmentation maximum résultant de l'apport d'azote fut de $r = +0.57$, et la relation de cette année-là n'est point substantiellement diminuée si l'on élimine l'effet de la date des semailles. Des divers facteurs énumérés plus haut les plus importants sont sans aucun doute les conditions physico-chimiques du sol conjointement avec les conditions climatériques. Sur de bonnes terres on obtiendra de bons rendements presque chaque année mais sur les terres pauvres (faibles ou détériorées) des variations des plus déconcertantes se produiront suivant que les conditions climatériques seront favorables ou non. Il faut généralement que deux facteurs défavorables entrent en jeu simultanément pour produire un déclin prononcé dans le rendement. Le cotonnier dans sa réaction à l'apport d'azote offre un contraste direct avec les autres cultures telles que le maïs, le blé et l'orge ; dans le cas de ces dernières les rendements faibles des témoins peuvent toujours être relevés par des applications convenables d'engrais azoté.

Azote assimilable du sol. —

Une analyse satisfaisante des résultats de ces essais de fumure n'est pas possible sans une estimation de l'azote assimilable existant dans le sol. Nous avons obtenu cette estimation en ce qui concerne des essais de fumure sur blé. Elle a été en concordance satisfaisante avec les rendements enregistrés. L'efficacité de l'azote du sol pour le blé varie, cependant, avec la température de la saison de croissan-

RAPPORT ENTRE LE RENDEMENT DES PARCELLES TEMOINS ET LA REPONSE A LA FUMURE
(Expériences de huit années)



ce ; par un hiver chaud il est plus effectif que par un hiver froid. Par analogie avec ces expériences sur blé on pourrait s'attendre à trouver une donnée pour l'azote assimilable plutôt pour le cotonnier cultivé dans le Delta méridional ou en Haute-Egypte que dans l'extreme Nord. Les résultats indiquent nettement que tel en est le cas, ceux de l'année 1938 étant particulièrement très encourageants. Le travail n'est pas encore assez avancé pour permettre ici une plus ample discussion.

Phosphate assimilable du sol. —

Le phosphate total aussi bien que le phosphate assimilable diminuent dans l'ensemble des terres égyptiennes avec la profondeur.

La rapidité de cette diminution varie, cependant, d'un endroit à l'autre.

La couche supérieure du sol est presque toujours bien pourvue en phosphate assimilable et, dans le cas du cotonnier, le superphosphate n'a d'effet que lorsque la dose d'acide phosphorique assimilable tombe au-dessous d'un certain degré quelque part dans le sous-sol. C'est pourquoi il est probable qu'on trouvera que le superphosphate est plus efficace pour les variétés à racines profondes, telles que le Sakel et le Guizeh 7 que pour l'Achmouni à racines moins enfoncées. De même, en considérant le pays dans son ensemble, la fumure phosphatée est plus importante pour les plantes à racines profondes comme le coton et le blé que pour celles à racines peu enfoncées comme le maïs et l'orge.

(Traduction **R.A.)**

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service
(Chemical Section)

BULLETIN No. 222

The Quantity, Distribution and Composition of the Organic Matter and Available Nitrogen in Egyptian Soils

BY

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(Recommended for publication by the Puplications Committee of the Ministry of Agriculture, which is not, as a body, responsible for the opinions expressed in this Bulletin)

Govt. Press, Bulâq, Cairo, 1939

Government Publications are on sale at the "Sale Room," Ministry of Finance. Correspondence relating to these publications should be addressed to the "Publications Office," Government Press, Bûlâq, Cairo.

Price - - - - - - - - - - P.T. 5

Contents

INTRODUCTION

The aim of this Bulletin is to attempt to provide the essential background against which the rational discussion of problems of nitrogenous manuring of agricultural crops in Egypt should take place. The contents are divided into three main sections. The first is devoted to a characterisation of the quantity, composition and distribution of organic matter in fertile perennially irrigated Egyptian soils, the second to a description of investigations into the mechanism of transformation of the various forms of nitrogen, and the third section to a short account of the progress so far made in applying the results to the definition of the manurial requirements of the various crops.

A considerable part of the discussion will inevitably be found to centre round the effect of *sharaqi* or drying. The term *sharaqi* should, of course, properly be reserved for the summer fallow to which soils under the basin system of irrigation are necessarily subject, and to which their long-continued fertility is in large measure attributed. The long period of drying in the hot summer months provides for thorough aeration of the soil through the extensive cracking which develops, while good drainage and the prevention of salt accumulation, are assured by the annual connection made with the underground water table when the basin is flooded (Mosséri and Audebeau, 1922). This treatment which basin land undergoes may be considered to have two distinct aspects : the immediate changes effected in the organic matter, etc., by drying and heating a soil and the long distance one of the maintenance of good physical properties through aeration and good drainage (Prescott, 1920 *a*). As the soils dealt with in this publication are almost exclusively under perennial irrigation it is the former aspect, *i.e.* the immediate effects of heating and drying, which is of principal concern, and the *sharaqi* periods of importance will be those intervals of fallow which occur between the harvesting of one crop and the planting of its successor. Deterioration of soils under perennial irrigation, by which is essentially meant deterioration in physical properties, is the result of bad drainage and always occurs where an unduly high water table has persisted for a sufficient length of time (Gracie et al., 1934). For various reasons, however, the soils examined in connection with the work reported on here can be regarded as having been relatively little affected from this point of view. It will nevertheless be seen that physical properties must be taken into account in interpreting any estimate of available soil nitrogen.

The beneficial effect of drying and heating a soil on its productivity has long been recognised and drying has been considered, for example, by Lebedjantzev (1924) to play an important part in the maintenance of soil fertility in hot countries. In Egypt, in explanation of the phenomenon, recourse has been had in the past to Russell and Hutchinson's (1909 and 1913) theory of partial sterilisation. Prescott (1920 *b*) and McKenzie Taylor and Chamley Burns (1922) postulated that the heating of the soil during *sharaqi* (temperatures of 50°–60° C. or more may be reached in the surface layers) caused not only a reduction in bacterial numbers but also the partial destruction of a harmful factor limiting bacterial activity. It was shown that on again moistening up the heating resulted in enhanced bacterial activity and increased production of nitrate as compared with the untreated soil. The facts presented here, however, lead to the much simpler conclusion that the effect of drying and heating during the *sharaqi* period is to increase the amounts of easily decomposable (and highly nitrogenous) organic matter in the soil. The latter, therefore, becomes a more suitable medium for bacterial activity and on moistening will naturally show a larger production of nitrate as compared with the same soil kept permanently moist. The effects may be regarded as being similar to what would be obtained by adding varying amounts of a highly nitrogenous organic material to the soils. Moreover, it must be emphasised that the factor of drying is at least as important as that of heat. (The above point of view has already been developed to some extent by the junior author, Khalil, 1929). In contrast to what was supposed by McKenzie Taylor and Chamley Burns (1922) the benefit of a *sharaqi* period is temporary and may largely be lost if the soil is irrigated, *i.e.* if bacterial activity is reintroduced too soon before the planting of the succeeding crop. The term "bacterial activity" is used advisedly and includes both nitrification and nitrogen assimilation by bacteria. The latter will be regarded as the sole agents responsible for the production of nitrate in Egyptian soils. Fraps and Sterges (1935) and Waksman and Madhok (1937) were unable to confirm the claims made by Dhar and his associates in India for photonitrification, recently summarised by the Imperial Bureau of Soil Science (monthly letter No. 63, 1937). Waksman and Madhok (1937) in addition showed the claims made by De Rossi (1935) for chemical nitrification to be unfounded.

Previous investigations into these questions with Egyptian soils, to which reference has already been made confined their attention mainly to the surface layer, and to the measures of bacterial activity and available nitrogen assumed to be represented by fluctuations in the amounts of ammoniacal and nitrate nitrogen. From the present investigations it will be seen that no adequate picture of the organic-matter status of the soils can be presented without taking into consideration the changing conditions in successive layers down to the depth of at least one metre; also that estimations of ammoniacal and nitrate nitrogen by themselves may give an inadequate indication of the power of a soil for supplying nitrogen to the plant. In view of the well-known uncertainty attaching to the interpretation of biological phenomena in the soil, and to the necessarily empirical nature of some of the methods of analysis used it is emphasised that whereever possible, a sufficient number of samples have always been examined as to enable the conclusions on any one point to have a statistical basis. For example, the important conclusion that the carbon nitrogen ratio in the organic matter of Egyptian soils increases progressively and significantly with depth, is based on the examination of forty-three profiles including a total of over one hundred and eighty samples, the analyses being carried out by different workers at different times.

The Quantity, Distribution and Composition of the Organic Matter and Available Nitrogen in Egyptian Soils

PART I

QUANTITY, DISTRIBUTION AND COMPOSITION OF THE SOIL ORGANIC MATTER

The whole of the investigations reported in this Bulletin take their origin in a systematic examination of a range of all types of Egyptian soils begun in 1931. The average organic carbon and total nitrogen content of the layers of nineteen profiles * of *fertile* soils included in that range are presented in Table 1. (Abnormal or deteriorated soils have been excluded since the organic matter present in them may be abnormal both in quantity and composition.)

TABLE 1.—THE AVERAGE ORGANIC CARBON, TOTAL NITROGEN AND C/N RATIOS OF THE NINETEEN PROFILES EXAMINED IN 1931, TOGETHER WITH THE AVERAGE RESULT OF FRACTIONATING THE ORGANIC MATTER BY 5 PER CENT CAUSTIC SODA †

Depth of layer	Number of samples	Organic carbon	Total nitrogen	Ratio C/N	Humus, *i.e.* Total organic matter (C×1·724)	"α Humus"	Nitrogen in "α Humus"	"α Humus" as % of total organic matter
		%	%		%	%	%	
0–20 cm.	19	0·90	0·082	11·0	1·56	0·53	3·10	34·6
20–40 ,,	19	0·64	0·056	11·4	1·11	0·40	2·89	35·7
40–60 ,,	14	0·53	0·042	12·6	0·91	0·34	2·87	36·1
60–80 ,,	9	0·55	0·043	12·8	0·95	0·36	2·63	37·5

Similar analyses have been made on twenty-four more complete profiles and the corresponding composite surface samples (to a depth of roughly 10 cm.) taken in connection with the 1935 cotton manurial experiments. They are averaged in Table 2. The sites of the experiments are distributed throughout Egypt from Mataana (Qena Province) in the south to the very north of the Delta.

* The soil profile is the soil considered in vertical section.

† The individual figures, together with details of the methods of analysis used, are given in appendix I.

TABLE 2.—THE AVERAGE ORGANIC CARBON, TOTAL NITROGEN AND C/N RATIOS OF THE TWENTY-FOUR PROFILES AND COMPOSITE SURFACE SAMPLES (C.S.S.) TAKEN FROM THE 1935 COTTON EXPERIMENTS.*

Layer	Organic carbon	Total nitrogen	Ratio C/N	
			Average	Range
	%	%		
C.S.S.	0·95	0·086	11·0	9·5–12·7
0– 25 cm.	0·84	0·074	11·4	9·6–13·9
25– 50 ,,	0·64	0·053	12·1	10·0–16·7
50– 75 ,,	0·57	0·044	13·0	10·2–16·1
75–100 ,,	0·53	0·039	13·6	10·7–16·5

The results in these tables bring out the two most outstanding features of the organic matter in Egyptian soils. It decreases slowly in amount with depth while at the same time its constitution alters, as is shown by the progressive increase in the carbon nitrogen (C/N) ratio. Even in the surface layer the actual amounts of organic matter present are, as would be expected in the soils of a hot country, small. If the conventional factor (1·724) be used to express the organic carbon as organic matter, then the composite surface samples (Table 2) contain on the average only 1·64 per cent, and given the highest figure for organic matter so far encountered in a (surface) soil in the course of these investigations it is only 2·27 per cent. This particular soil came from Deirut (Assiut Province) and is included in the average given in Table 1.

Fractionation of the organic matter

Four of the twenty-four profiles averaged in Table 2 were selected for further examination by fractionation of the total organic matter present (*see* Table 3). Two (Nos. 20 and 27) represent soils which, from internal evidence obtained in the experiments carried out on them, are well supplied with available nitrogen ; and two (Nos. 31 and 39) are soils where the evidence pointed to a nitrogen deficiency. No. 39 in particular represents a soil (from Mataana) which is extremely deficient in both total and available nitrogen. The method of fractionation used was a modification of that proposed by Waksman and Stevens (1930) as follows :—

Extractions with ether, alcohol and 2 per cent hydrochloric acid were omitted and 50 gm. of the air-dried soil were treated with 25 ml.

* The individual figures, together with details of the methods of analysis used are given in appendix I.

of 78–80 per cent sulphuric acid in the cold for 2–3 hours. The mixture was then diluted with distilled water to give a 5 per cent solution of the acid and heated in the autoclave for half an hour under a pressure of one atmosphere. The filtered residue was dried, weighed and analysed for total (residual) organic carbon and nitrogen. The residual organic matter present after the hydrolysis may be regarded as consisting almost entirely of: (*a*) lignin * and its transformation products and (*b*) "resistant protein", probably mainly of microbial origin (Waksman, 1936). Table 4 shows that prolonging the time of heating in the autoclave does not further reduce the amount of organic carbon in the residue so that the separation effected is quite definite.

The sulphuric acid treatment results in the complete hydrolysis of any celluloses present to reducing sugars, so that these may be present in the filtrate in addition to what is termed the "hydrolysable protein". Owing to experimental difficulties (very large amounts of iron, aluminium, etc., are brought into solution by the acid) no quantitative estimations of reducing sugars were made, but qualitative tests showed the amounts present to be small in most cases, or altogether absent. Celluloses will be regarded as making negligible contribution to the soil organic matter, and the latter as being effectively made up of three main fractions: the hydrolysable protein brought into solution by the acid and the lignin* and resistant protein represented by the organic carbon and total nitrogen of the residue. An exception to this statement will be made in the case of the composite surface sample of No. 31 in Table 3.

The results of the fractionation given in that table show at once that the increase in the C/N ratio with depth is associated with an increase in the proportion of lignin. The actual amount of the latter remains relatively constant in all layers of any given profile (*see* figures for lignin carbon) and the C/N ratio increases with depth, because of the progressive decrease in both hydrolysable and resistant protein. The correlation between the proportion of lignin in humus and the C/N ratio of the original soil is significant ($P = \angle\, 0{\cdot}05$) and works out at $r = +\ 0{\cdot}566$. This figure is arrived at without the composite surface sample of No. 31 where the proportion of lignin is low (40·3 per cent) and where the figure for the C/N ratio, which is high for a surface soil (12·4), is almost certainly influenced by the presence of exceptional amounts of celluloses. This composite surface sample of No. 31 is the only sample in which the C/N ratio was diminished by the hydrolysis (from 12·4 in the original to 11·6 in the residue). The correlation between the proportion of lignin in humus and the C/N ratio of the residues, *i.e.* with the disturbing effect of celluloses removed, rises to $r = +\ 0{\cdot}848$.

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* The lignin and resistant protein are, for the sake of convenience, treated as distinct and separate fractions of the soil organic matter, but it would, of course, be more correct to speak of a "lignin-protein" complex.

TABLE 3.—RESULTS OF THE FRACTIONATION OF THE SOIL ORGANIC MATTER IN FOUR PROFILES AND A SAMPLE OF NILE SILT BY THE SULPHURIC ACID METHOD.

Soil No.	Depth of layer	Total organic carbon	Total nitrogen	Ratio C/N	Humus, *i.e.*, total organic matter (C×1·724)	Residual carbon	Residual nitrogen	Hydrloysable nitrogen (by difference)	Ratio C/N in residue	Residual nitrogen × 6·25	Lignin carbon	Lignin in humus †
		%	%		%	%	%	%			%	%
20 C35	C.S.S.*	0·98	0·103	9·5	1·69	0·79	0·072	0·031	10·9	0·45	0·56	53·5
	0– 25 cm.	0·75	0·075	10·0	1·30	0·53	0·041	0·034	12·9	0·26	0·40	50·8
	25– 50 ,,	0·59	0·054	10·9	1·02	0·46	0·032	0·022	14·5	0·20	0·36	58·9
	50– 75 ,,	0·51	0·042	12·2	0·88	0·45	0·029	0·013	15·6	0·18	0·36	67·4
	75–100 ,,	0·50	0·043	11·7	0·87	0·43	0·028	0·015	15·4	0·18	0·36	65·8
27 C35	C.S.S.	0·82	0·082	10·0	1·42	0·52	0·044	0·038	11·8	0·28	0·38	44·0
	0– 25 cm.	0·80	0·073	11·0	1·38	0·50	0·041	0·032	12·4	0·26	0·38	45·0
	25– 50 ,,	0·68	0·055	12·3	1·17	0·48	0·033	0·022	14·5	0·21	0·37	52·8
	50– 75 ,,	0·68	0·051	13·3	1·18	0·55	0·030	0·021	18·3	0·19	0·46	64·6
	75–100 ,,	0·63	0·046	13·7	1·09	0·50	0·030	0·016	16·7	0·19	0·41	62·3
31 C35	C.S.S.	1·10	0·089	12·4	1·90	0·65	0·056	0·033	11·6	0·35	0·47	40·3
	0– 25 cm.	0·89	0·075	11·9	1·54	0·66	0·047	0·028	14·0	0·29	0·51	54·4
	25– 50 ,,	0·73	0·057	12·9	1·27	0·55	0·038	0·019	14·5	0·24	0·43	56·5
	50– 75 ,,	0·70	0·054	12·9	1·21	0·55	0·036	0·018	15·2	0·23	0·44	59·8
	75–100 ,,	0·68	0·049	13·8	1·16	0·52	0·033	0·016	15·8	0·21	0·42	59·6
39 C35	C.S.S.	0·64	0·052	12·2	1·09	0·53	0·034	0·018	15·5	0·21	0·42	63·3
	0– 25 cm.	0·49	0·044	11·1	0·84	0·39	0·026	0·018	14·8	0·16	0·30	59·5
	25– 50 ,,	0·51	0·045	11·2	0·87	0·40	0·025	0·020	15·8	0·16	0·32	60·3
	50– 75 ,,	0·47	0·035	13·5	0·82	0·38	0·024	0·011	15·7	0·15	0·30	61·0
	75–100 ,,	0·46	0·038	12·1	0·79	0·38	0·023	0·015	16·5	0·14	0·31	64·4

Nile silt	—	1·11	0·086	12·9	1·91	0·89	0·064	0·022	13·9	0·40	0·69	59·6

* C.S.S. = Composite surface sample taken to a depth of roughly 10 cm.

† Calculated from the formula $\frac{a \times 100}{A} - \frac{b \times 100}{S}$

Where a = Carbon content in sulphuric acid residue calculated on basis of the total original sample of soil.
A = Total organic carbon content of soil.
b = Protein in sulphuric acid residue.
S = Total organic matter in the soil, as determined from the organic carbon (C × 1·724) (after Waksman and Stevens, 1930).

TABLE 4.—EFFECT OF INCREASING THE TIME OF HEATING WITH SULPHURIC ACID ON THE AMOUNT OF RESIDUAL CARBON

Soil No.	Layer	% residual carbon after :	
		½ hour heating in autoclave	1 hour heating in autoclave
27	0–25 cm.	0·50	0·52
27	75–100 ,,	0·50	0·55
31	C.S.S.	0·65	0·68

In the case of the first series of soils examined (Table 1) after determining total organic carbon and total nitrogen, further portions of the soils were attacked with 5 per cent caustic soda in the autoclave under pressure, and the "α humus" or "humic acid" was precipitated from the filtered extract by the addition of hydrochloric acid. The precipitate was then filtered off, dried, weighed and the total nitrogen determined. The caustic soda attacks the ligno-protein complex but the fractionation of the soil organic matter obtained through its use is said to be (Waksman, 1936) very much less definite than that effected by the sulphuric acid method. The averaged figures given in Table 1 lead, however, to substantially the same conclusion, namely, that the increase in the C/N ratio with depth is associated with an increase in the proportion of lignin. The proportion of "α humus" in the organic matter increases with depth, while the percentage of nitrogen in that "α humus" itself decreases.

The relative constancy of the lignin carbon content is responsible for another feature of the results averaged in Table 2. The organic carbon contents of the first and second layers of these twenty-four profiles are significantly and positively associated ($r = +0{\cdot}635$); between the second and third layers the association is expressed by $r = +0{\cdot}696$; while between the third and fourth layers it rises to $r = +0{\cdot}804$. Between the first and third layers the correlation is still substantial at $r = +0{\cdot}463$, but between the first and fourth it falls to the low (and insignificant) value of $r = +0{\cdot}228$. The corresponding figures for the correlations between the total nitrogen contents of adjacent layers are $r = +0{\cdot}648$ for the first and second, $r = +0{\cdot}701$ between the second and third, and $r = +0{\cdot}811$ between the third and fourth. This increase in the association of the organic carbon content of adjacent layers with their depth is taken to be a further expression of the fact that the amount of lignin present is a characteristic feature of each profile, *i.e.* that the amounts of lignin carbon ramain relatively constant (but at varying levels) in all layers of any given profile, and the correlation tends to be less marked in the surface layers because of the masking effect of the greater and more variable amounts of hydrolysable and resistant protein present there. The association between the total nitrogen contents of adjacent layers occurs merely because the total nitrogen and organic carbon within each layer are themselves significantly correlated ($r = +0{\cdot}865$ for the surface, and $r = +0{\cdot}818$ for the bottom layers), a fact which is emphasised below.

Origin of the organic matter

All of the soils dealt with here were, of course, built up originally from successive deposits of silt laid down by the flood waters of the Nile. V. M. Mosséri (1936) gives the average organic carbon content of the air-dried material in suspension in the flood water of the Nile in Cairo during the month of September in the years 1925, 1926 and 1927 respectively as 1·58, 1·47 and 1·51 per cent. The corresponding figures for total nitrogen in 1925 and 1926 are 0·150 and 0·115, giving a C/N ratio for the organic matter of the silt of 10·5 and 12·8 respectively for the two years. The figures (*see* Table 3) obtained on a sample of freshly deposited silt (1936 flood) taken from the banks of the Nile near Cairo show an organic carbon content of 1·11 per cent and, with the total nitrogen at 0·086 per cent, a C/N ratio of 12·9. The actual quantity of organic matter in this sample is less than that given by Mosséri since it is derived from the coarser fractions only of the material in suspension in the water, which are poorer in total nitrogen than the finer fractions (Mosséri, 1936). It would appear from Mosséri's figures that the constitution of the organic matter in the silt may be a characteristic of any given flood. In 1925 the average C/N ratio of 10·5 for September remained the same in October and sank to 9·1 in the November silt. The higher September ratio of 12·8 in 1926 was equally maintained practically constant at 12·7 in October and fell only to 9·5 in November. The 1926 flood was higher than that of 1925 and the amount of sediment in suspension approximately 30 per cent greater. W. C. Mackenzie (1905) gives a total nitrogen content of 0·12 per cent in the August silt of the high flood of 1898, as against 0·17 for the same month in the low flood of 1899, there being again a much greater amount of silt in suspension in the former year.

It is impossible to say exactly what the average constitution of the organic matter of the flood water is. If it tends to be like that of 1926 and have an average C/N ratio of 12·8 then, from the figures for the sample of Nile silt given in Table 3, sixty per cent of it will be accounted for by lignin alone and eighty per cent by the lignin and resistant protein, and it will closely resemble the subsoil organic matter of the perennially irrigated soils of Table 3. Starting with such a material it becomes clear that, with perennially irrigated soils, the ratio of carbon to nitrogen in the surface layers has become reduced (and the total organic matter increased) as compared with the subsurface layers, through the accumulation of residues of organic matter additions made in the course of their exploitation. As regards quantity, taking Mosséri's (1936) figures as the more accurate, and neglecting the disturbing effect of the subsequent additions just mentioned, the amounts of organic matter present in perennially irrigated soils are roughly one-third to one-half of that present in the original silt. Such a comparison may have no real practical meaning, since all of the material suspended in the flood water (on which Mosséri's figures are based) is not deposited—it has been seen that the finer fractions are richer in nitrogen. Some reduction may also have taken place in the basin land prior to its conversion to perennial irrigation. The real starting point for the comparison should, therefore, be the basin land itself, and a number of profiles from such land are now under examination in order to obtain information on this and other points. The results will render possible a fuller discussion of the general question whether the organic matter status of soils under perennial irrigation is on the whole being increased, maintained at a relatively constant level, or being gradually reduced ? In the case of soil No. 39 of Table 3, which had been cultivated for a long period without the addition of organic manures, the hydrolysable protein in the surface layers is so low that the total amounts of organic mater are approximately the same in all layers. These amounts are also low but, since the composition remains roughly the same as in the subsoils of the other profiles, it is to be presumed that the various constituents of the organic matter have been undergoing reduction in proportion to the amounts present. From this it can also be concluded that the organic matter in Egyptian soils is on the whole in an advanced state of decomposition.

Importance of the carbon/nitrogen ratio

The C/N ratio is of fundamental importance to the discussion in the succeeding section of this Bulletin, because it determines the course of events when the soil organic matter is undergoing decomposition by bacteria. Before the decomposition of carbonaceous compounds can proceed (such as lignin and cellulose) a supply of readily assimilable nitrogen must be available. Where the amounts of these carbonaceous compounds are relatively high, *i.e.* where the C/N ratio is high, the available nitrogen produced by the decomposition of nitrogenous compounds (or added in the form of fertiliser) will necessarily tend to be assimilated to a greater extent for their decomposition than in cases where the ratio is low. The main reserve of nitrogen of immediate importance lies in the hydrolysable protein, but whether any nitrogen becomes available for plant growth or not will depend not only on its actual amount but also on the proportion it bears to the lignin fraction. The picture presented, therefore, is one of the whole of the organic matter of the soil undergoing slow decomposition, and of nitrogen becoming available in suitable amounts for plant growth only if the hydrolysable protein fraction is sufficiently large, and if the process of its ammonification is producing sufficiently more available nitrogen than is required for the lignin (and cellulose) decomposition. In this connection it is notable that the surface layers of the two soils of Table 3 (Nos. 31 and 39) chosen as being deficient in available nitrogen not only contain smaller amounts of hydrolysable protein but also have higher C/N ratios than the two (Nos. 20 and 27) chosen as being well supplied with available nitrogen. On the whole the tendency will be for variable amounts of available nitrogen to result from bacterial activity in the surface layers of the soils, but as the C/N ratio increases with depth the tendency will be increasingly towards assimilation of available nitrogen. The actual course of events will vary from point to point even within any one profile according to conditions, a considerable variety of conditions being provided for by the range in value shown by the C/N ratios of the various layers of the profiles averaged in Table 2. This aspect of the situation is of considerable practical interest since it means that any excess of a nitrogenous fertiliser not utilised by a growing crop will not necessarily be washed out of the soil but may be assimilated by micro-organisms and take the form of microbial protein. Part of the nitrogen in microbial protein is accounted for by nitrogenous compounds difficult of decomposition which will contribute to the "resistant protein" (Jensen, 1932). The latter is in turn slowly decomposed, and will add to the supply of hydrolysable protein; so eventually again to assimilable nitrogen.

Summary of Part I

(1) The amount of organic matter present, even in the surface layers of perennially irrigated Egyptian soils, is small but it shows (the organic matter) two important features: (*a*) the rate of decrease with depth is slow and (*b*) the decrease is accompanied by a progressive increase in the C/N ratio (from an average of 11·0 in the surface to 13·6 at one metre).

(2) The organic matter is composed of three main fractions: hydrolysable protein, resistant protein and lignin. The increase in the C/N ratio with depth is associated with an increase in the proportion of lignin and a decrease in the amounts of hydrolysable and resistant protein.

(3) As an explanation it is suggested that the amounts of organic matter in the soils as originally laid down and the C/N ratio were approximately the same in all layers, but that the C/N ratio in the surface has become reduced through the accumulation there of organic matter residues in the form of hydrolysable and resistant protein.

(4) The practical importance of the C/N ratio in the nitrogen cycle is pointed out.

PART II

THE AVAILABLE NITROGEN IN EGYPTIAN SOILS

The information presented in this section was obtained partly in liason with the extensive series of manurial experiments on various crops conducted annually by the Ministry of Agriculture, and partly in connection with observations made on the effects of drying and heating soils (*sharaqi* effects), including observations on the method of treating *sharaqi* land in preparation for a crop.

Estimation of available nitrogen

The object of the laboratory work with the manurial experiments is to obtain suitable estimates of available soil nitrogen, capable of being correlated with the yields recorded in the experiments.

The possible importance of the subsoil organic matter in the nitrogen cycle in the soils has already been indicated in Part I. From the considerations there advanced it is obvious that the subsoil organic matter may be a source of available nitrogen under some conditions and in others may be the cause of its being assimilated. For practical purposes it may, therefore, be necessary to take account of the whole soil down to a depth of at least one metre. The soil in each experiment is accordingly sampled at sowing-time to that depth by taking four successive layers of 25 cm. from a hole dug just off the edge of the experiment. A composite surface sample is at the same time taken from the control plots, to a depth of approximately 10 cm. The only exception to the above procedure is made in the case of maize experiments, where the shallow-rooted nature of the crop and its short period of growth permit one to suppose that sampling to a depth of 50 cm. may be adequate.

Estimation of available nitrogen by incubation experiments

A beginning was made with the 1934 cotton experiments, eight of which were sampled in the manner described. The fresh samples were brought into the laboratory, made up at once in amounts of 100 gm. (based on the oven-dry weight) and incubated at 30° C.

at a uniform moisture content made equal to 70 per cent of the water-holding capacity. The ammoniacal and nitrate nitrogen were estimated at once in the fresh samples and at intervals of 10, 20 and 30 days in the incubated samples. Incubation experiments are still being carried on and the detailed results will be reported in a separate publication. For the present they can be summarised briefly as follows: The incubation of composite surface samples and of the surface layers (0–25 cm.) of the profiles always results in some increase (and in some cases very considerable increases) in the ammoniacal and nitrate nitrogen. (These samples contain on the whole greater amounts of hydrolysable protein, the main reserve of available nitrogen, than the subsoil samples.) Incubation of the subsurface samples may give a variety of results. At one extreme there are cases where all of these layers in a profile showed continuous increase and at the other extreme are cases where all showed continuous diminution. Intermediate examples provide profiles in which only the bottom layer (75–100 cm.) may show assimilation, and so on. It also happens frequently that an abrupt initial increase in the ammoniacal and nitrate nitrogen is followed by assimilation.

The estimation of the available nitrogen by determining the amount mineralised or assimilated on incubation is considered preferable to the procedure finally adopted and described below, but from a practical point of view it suffers from two obvious defects. The labour involved is too great to enable the necessary number of samples to be examined, and it is very probable that the conditions obtaining during the incubation may bear no relationship at all to those prevailing in the field.

Estimation of available nitrogen by chemical methods

As a substitute for the incubation method of estimating the amount of mobilisable nitrogen present (in addition to the initial ammoniacal and nitrate nitrogen) hydrolysis by dilute sulphuric acid was adopted, following a suggestion offered by the work of Tiurin and Kononova (1934 and 1935).

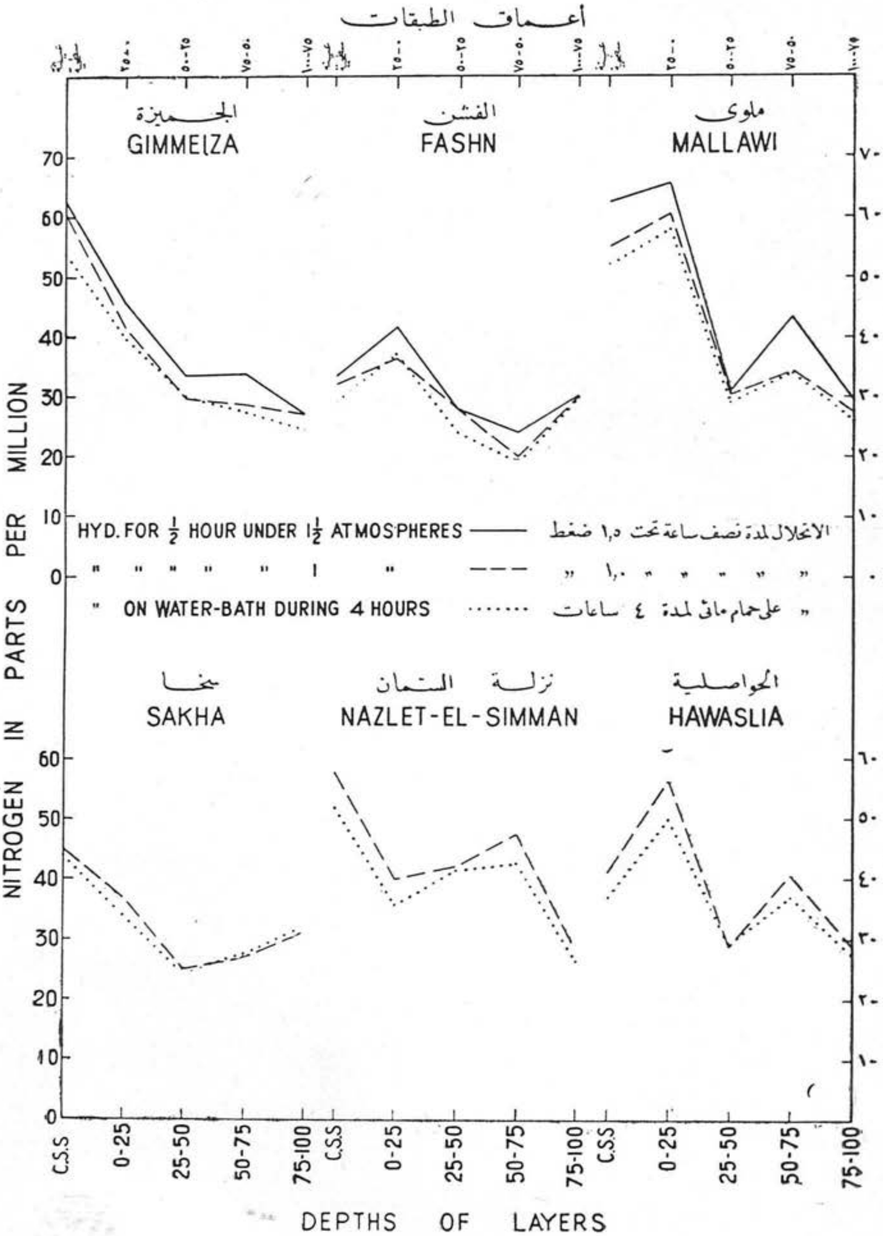
The procedure finally adopted for the determination of the available nitrogen is as follows: The soil samples on arrival in the laboratory are air-dried and a sub-sample powdered to pass the one-millimetre sieve. For the determination of ammoniacal and nitrate nitrogen 100 gm. of the soil are shaken up during half an hour

FIG. I

شكل رقم ١

THE EFFECT OF VARYING THE CONDITIONS OF HEATING ON THE AMOUNT OF HYDROLYSABLE NITROGEN BROUGHT INTO SOLUTION

أثر تغيير ظروف التسخين فى الكمية المذابة من الأزوت القابل للانحلال



with 250 ml. normal sodium chloride (A.R.) solution. The mixture is then filtered at the pump and the soil leached with further portions of the salt solution until the filtrate reaches a total volume of 750 ml. The extract is then transferred to a distillation flask, the nitrate reduced by Devarda's alloy and the ammonia distilled into standard acid. The estimation of what will be termed "hydrolysable" nitrogen is carried out by heating a further portion of 50 gm. of the soil with 500 ml. tenth normal sulphuric acid in the autoclave under one atmosphere pressure during half an hour. The soil is then filtered off, washed with distilled water and the extract and washings transferred to a distillation flask. The nitrate is then reduced by Devarda's alloy and the ammonia distilled into standard acid. Deduction of the ammoniacal and nitrate nitrogen then gives the figure for "hydrolysable" nitrogen. It is, of course, essential to run blanks for the reagents. If the divergence between duplicate estimations exceeds 1·5 parts per million in the case of the ammoniacal and nitrate nitrogen or 3 parts per million in the case of the hydrolysable, the estimation is repeated until concordant results within these limits are obtained. The *mean* divergence between duplicates works out at $\pm$ 1 p.p.m. of the air-dried soil for the ammoniacal and nitrate nitrogen and is slightly greater for the hydrolysable nitrogen. The determinations must be made *as soon as possible* after the arrival of the samples in the laboratory.

Figure I shows the effect of varying the conditions of heating in the hydrolysis. Where these are made more severe proportionately more hydrolysable nitrogen is brought into solution, the upper limit being presumably the whole of the hydrolysable protein fraction. The part of this fraction of the total organic matter actually measured by the method is purely arbitrary, and comparable and reproducible results can only be secured by a rigid adherence to the details of the method as laid down. Heating in the autoclave was adopted because of rapidity in working. The strength of the acid and the ratio of soil to solution were originally chosen so as to allow of the decomposition of the average amount of calcium carbonate in the general run of Egyptian soils and leave a suitable excess for the hydrolysis. Table 5 shows that the addition of further acid, while lowering the final pH values, does not necessarily increase the amounts of nitrogen brought into solution and that such increases as do occur cannot in any case be related to the calcium carbonate present. The soils in the table have been arranged in descending order of calcium carbonate content.

TABLE 5.—THE EFFECT OF INCREASING THE ACIDITY ON THE AMOUNTS OF HYDROLYSABLE NITROGEN BROUGHT INTO SOLUTION

Soil No.	Depth of layer	P.p.m. H.N.+NH_3—N +NO_3—N		Final pH values		% Ca CO_3
		Ordinary method	Increased acid	Ordinary method	Increased acid	
15 C35	C.S.S.	37·0	37·2	3·55	2·22	5·62
24 ,,	25–50 cm.	16·5	20·0	2·55	—	5·40
15 ,,	0–25 ,,	31·0	32·2	2·80	1·95	4·98
15 ,,	25–50 ,,	22·0	21·6	2·76	1·92	4·63
24 ,,	0–25 ,,	26·0	32·5	2·55	—	4·48
4 ,,	0–25 ,,	39·6	43·7	2·39	1·98	4·43
21 ,,	0–25 ,,	30·0	28·0	2·29	2·19	3·88
26 ,,	0–25 ,,	34·9	39·9	2·59	—	3·88
4 ,,	C.S.S.	48·0	54·4	2·52	1·83	3·75
32 ,,	0–25 cm.	34·3	40·5	2·31	—	3·29
2 ,,	0–25 ,,	38·0	37·6	2·92	1·83	2·92
39 ,,	C.S.S.	29·6	27·6	2·24	1·74	2·21

Relationship between total and available nitrogen

Samples from the various series of experiments from 1935 onwards have been systematically examined by the methods described. Total nitrogen estimations have been made also on most of the cotton soil samples for 1935, and on the surface layers (0–25 cm. and 25–50 cm.) of the profiles from the cotton experiments of 1936 and 1937. The individual figures will be given in separate bulletins dealing with each crop. In the meantime certain general features of the results which are relevant to the present discussion can be illustrated from the average figures for available nitrogen, for each series, given in Table 6 and from Figure 2. In that figure the available nitrogen (*i.e.*, the hydrolysable plus ammoniacal and nitrate nitrogen) has been plotted against the total nitrogen for 260 soil samples from the 1935–1937 cotton experiments. The correlation between the two estimates of nitrogen works out at $r = + 0{\cdot}618$, so that the amount of available nitrogen present in a soil may be regarded as being decided primarly by the total nitrogen present. The fraction of the soil organic matter which is most important as a provider of immediate nitrogen supply is the hydrolysable protein. This fraction of the total organic matter probably originates mainly from the residues of additions of organic matter which have been made subsequently to the deposition of the soil. That is to say, that the nitrogen status of a soil or its power of supplying nitrogen for plant growth, is in the first place (as would be expected) the natural consequence of its long-period treatment in cultivation.

FIG. 2

شكل رقم ٢

RELATIONSHIP BETWEEN TOTAL AND AVAILABLE NITROGEN

العلاقة بين الأزوت الكلى والأزوت الصالح

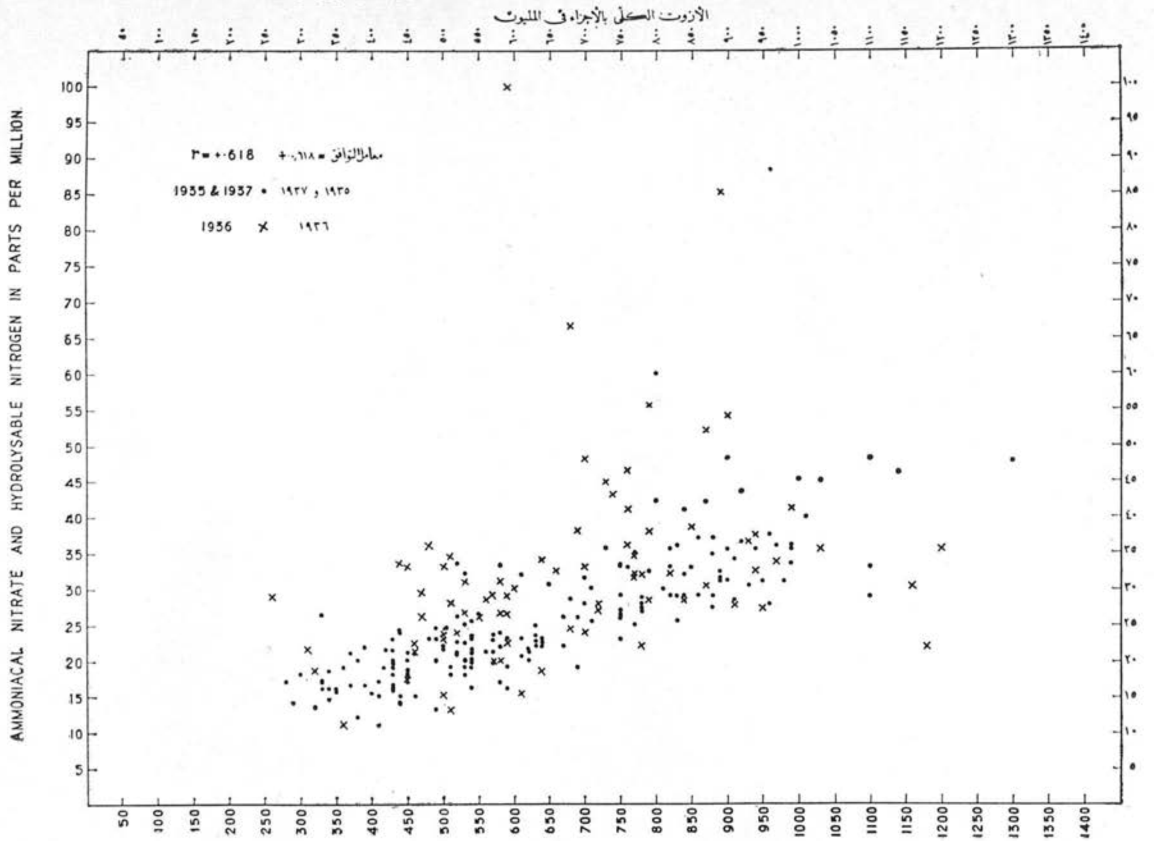
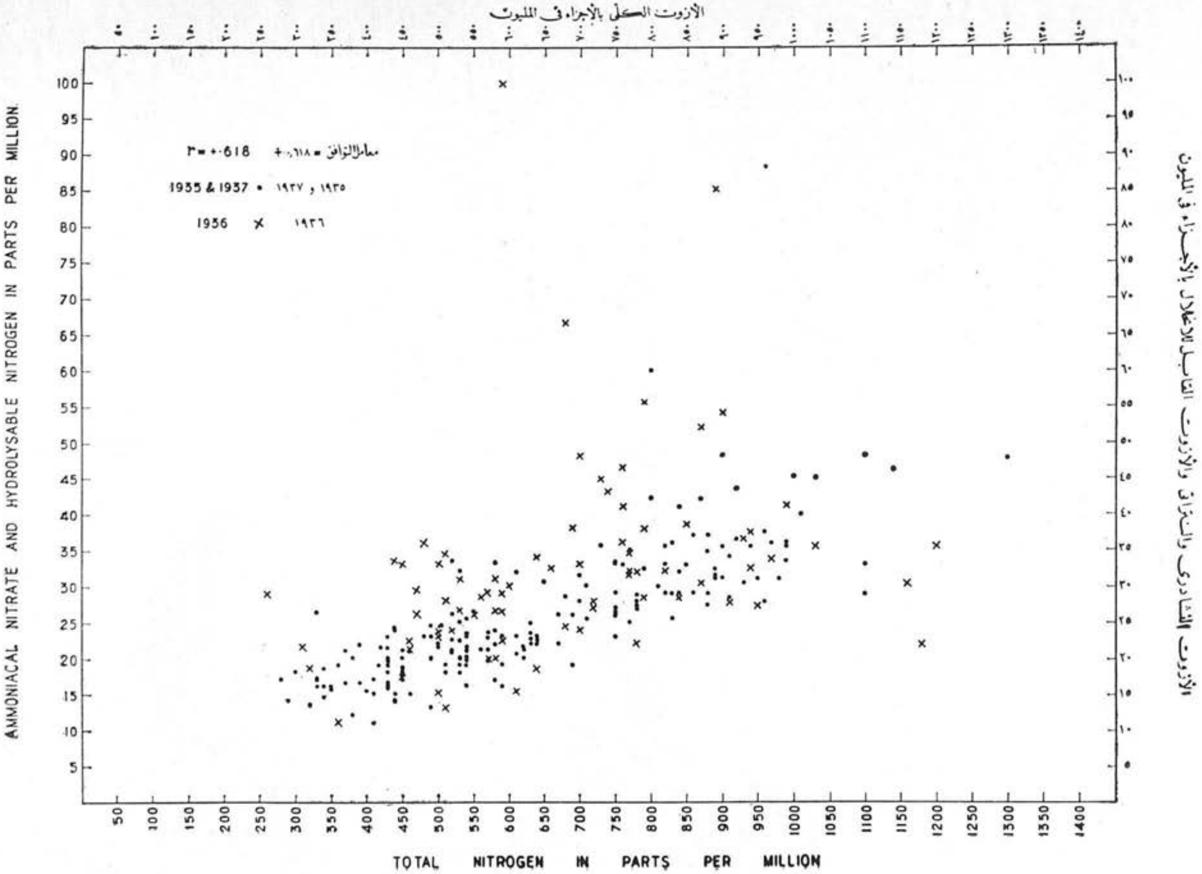


FIG.2

شكل رقم ٢

RELATIONSHIP BETWEEN TOTAL AND AVAILABLE NITROGEN

العلاقة بين الأزوت الكلى والأزوت الصالح



Amount and composition of the available nitrogen

The results from the 1936 samples plotted in Figure 2 have been distinguished by the use of crosses to show that in these soil samples there is a distinct tendency for a given quantity of total nitrogen to be associated with a greater amount of available nitrogen than in the other two years. Moreover, it can be seen from Table 6 that the layers of the profiles from the 1936 cotton experiments contain on the whole larger amounts of available nitrogen than any other series.

TABLE 6.—THE AVERAGE AVAILABLE NITROGEN CONTENT IN PARTS PER MILLION (P.P.M.) AND THE AVERAGE RATIOS OF AMMONIACAL AND NITRATE NITROGEN TO HYDROLYSABLE NITROGEN FOR THE SOIL SAMPLES TAKEN FROM VARIOUS SERIES OF EXPERIMENTS :—

(a) *Cotton Experiments*

Year	1935 (41 expts.)			1936 (39 expts.)			1937 (31 expts.)			1938 (32 expts.)		
Layer	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio
C.S.S.	27·3	15·1	1·57	27·4	17·5	1·57	19·6′	21·2	0·92	18·6	19·4	0·96
0–25cm.	17·5	13·8	1·27	20·5	20·5	1·00	15·0	19·4	0·77	18·2	18·8	0·97
25–50 ,,	10·3	9·5	1·08	13 5	14·0	0·96	8·6	14·2	0·61	7·0	11·4	0·61
50–75 ,,	9·2	9·2	1·00	11·9	11·8	1·01	7·2	12·3	0·59	5·7	9·4	0·61
75–100,,	9·3	8·1	1·15	11·6	12·0	0·97	6·7	11·2	0·60	5·6	8·5	0·66

(b) *Wheat and Barley Experiments*

Year	1935–1936 (36 expts.)			1936–1937 (33 expts.)			1937–1938		
Layer	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio
C.S.S.	20·0	18·9	1·06	21·6	17·6	1·22	23·6	20·3	1·16
0– 25 cm.	13·3	17·0	0·78	13·7	16·5	0·83	20·1	18·0	1·12
25– 50 ,,	9·7	13·6	0·71	7·7	12·9	0·60	7·4	13·2	0·56
50– 75 ,,	7·2	11·9	0·61	6·6	12·4	0·53	4·7	11·3	0·42
75–100 ,,	11·1	11·2	0·99	6·1	11·4	0·53	4·6	10·0	0·46

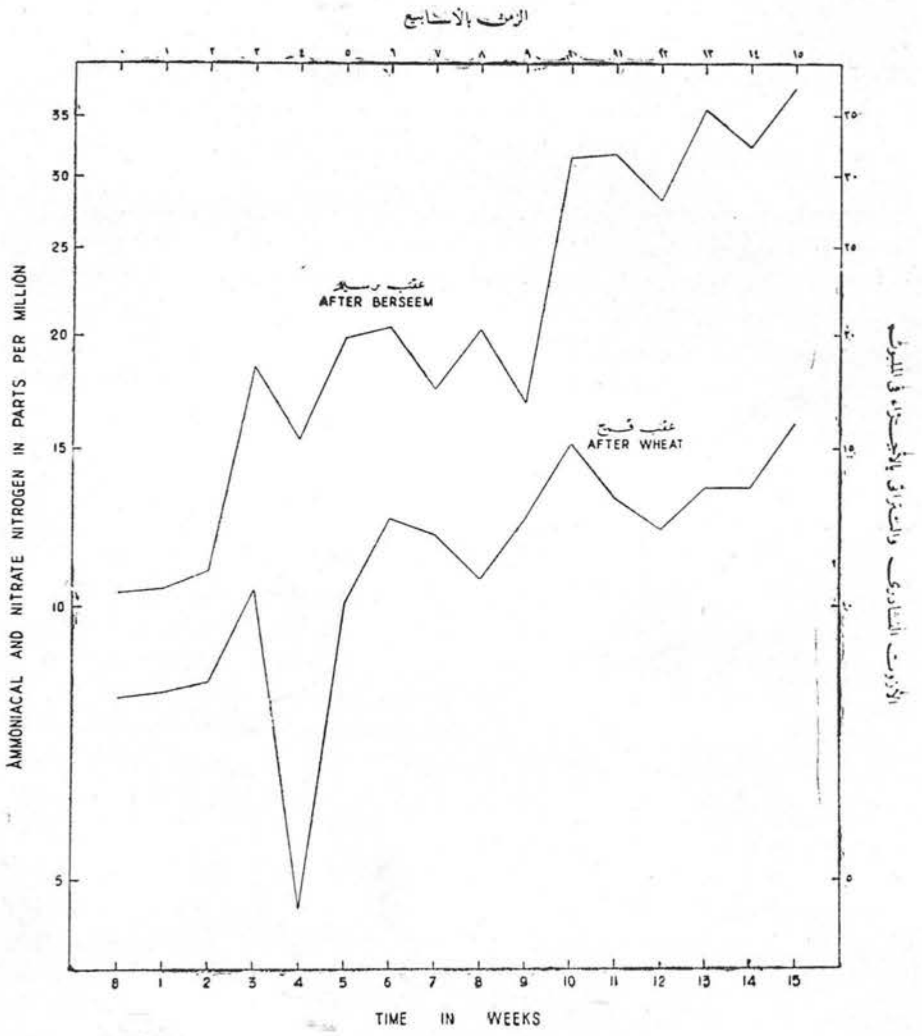
(c) *Maize Experiments*

Year	1935 (23 expts.)			1936 (33 expts.)			1937 (26 expts.)
Layer	NH_3—N + NO_3—N	H.N.	Ratio	NH_3—N + NO_3—N	H.N.	Ratio	Total available nitrogen
C.S.S.	22·9	18·6	1·23	21·5	17·0	1·27	36·7
0–25 cm.	12·4	17·6	0·71	14·6	15·9	0·92	31·2
25–50 „	7·9	14·9	0·53	7·7	13·0	0·59	20·9

The winter of 1935–1936 was exceptionally warm, and while the amount of available nitrogen must primarily be determined by the total, it is secondarily and strongly influenced by the severity of the heating and drying to which the soil has been subjected. (This will be demonstrated from the *sharaqi* experiments described below.) In addition to this influence on quantity the duration and intensity of the drying period may possibly affect the quality of the available nitrogen, as indicated by the ratio of the ammoniacal and nitrate part to the hydrolysable. This ratio is always higher in the surface layers—the first to dry out—and decreases with depth. The 1935 and 1936 cotton samples provide an exception to the others, in that the ratio is maintained at a uniformly higher level in all layers of the profile than in any of the other series. In their case the average proportion of ammoniacal and nitrate nitrogen to the hydrolysable is always unity or above and there is a definite tendency for the relationship between the two forms to be inverse. The association reached significance ($r = -0{\cdot}419 \pm 0{\cdot}16$) in the layers extending between 50–75 cm. in 1936 and a bare significance in those from 75–100 cm. ($r = -0{\cdot}301 \pm 0{\cdot}16$) in 1935. A possible explanation for part of the differences in the ratio between the various series of experiments may lie in the length of time during which the land has lain fallow between crops, and in the temperatures during that period. Thus, in these experiments the cotton is grown chiefly after maize, with a resting period of three and a half months; approximately half of the maize is grown after berseem (clover) and half after wheat, with a resting period of two to two and a half months, while wheat is grown principally after cotton, with the shortest resting period of all. The causes of variations in the ratio are

FIG. 3
THE EFFECT OF SHARAQI ON THE AMOUNT OF AMMONIACAL AND NITRATE NITROGEN

شكل رقم ٣
أثر الشراقي في مقدار الأزوت النشادري والنتراتي



evidently very complex. The question is referred to again below in connection with the effects of storing the soil in an air-dry condition in the laboratory, while the importance of this ratio in the growth and manuring of wheat will be touched on in Part III.

Effects of sharaqi or drying

The progressive increase in the ammoniacal and nitrate nitrogen fraction of the available nitrogen during *sharaqi* was followed at Giza in the summer of 1934. Two plots of land 1/40th feddan in area (one after berseem and the other after wheat) were left bare fallow all summer. Composite surface samples to a depth of 15 cm. were taken from them at weekly intervals beginning on June 26. The samples were brought into the laboratory, passed through the one millimetre sieve and the ammoniacal and nitrate nitrogen estimated in the usual way. The results are given in Table 7 and illustrated in Figure 3. From these it is seen that, if allowance be made for sampling error, there was a continuous increase in the ammoniacal and nitrate nitrogen with time during the whole period of the *sharaqi*. The extent of the increase is very much greater in the land after berseem, but in neither case is there any indication than an end point in the process had been reached.

TABLE 7.—THE EFFECT OF SHARAQI ON THE AMOUNT OF AMMONIACAL AND NITRATE NITROGEN

Time	NH_3—N+NO_3—N in p.p.m.		Time	NH_3—N+NO_3—N in p.p.m.	
	Berseem (clover)	Wheat		Berseem (clover)	Wheat
Initial	10·4	7·9	8th week	20·3	10·7
1st week	10·5	8·1	9th ,, ...	16·8	12·5
2nd ,, ...	11·0	8·3	10th ,, ...	31·5	15·7
3rd ,, ...	18·5	10·5	11th ,, ...	31·8	13·2
4th ,, ...	15·3	4·4	12th ,, ...	28·2	12·2
5th ,, ...	19·9	10·1	13th ,, ...	35·5	13·5
6th ,, ...	20·4	12·5	14th ,, ...	32·2	13·5
7th ,, ...	17·5	12·0	15th ,, ...	37·5	16·0

The bulk of the evidence on the effect of drying is summarised in Table 8. It has been obtained by determining the available nitrogen in soils after various periods of storage in the laboratory in the air-dry condition, and comparing the result with the amount initially present. The samples on which the re-determinations were made were chosen at random from each series and all layers of the profiles are approximately equally represented. The averaged results from each series (Table 8A) show that while the total available nitrogen on the whole increases on storage, there is considerable variation between the different series (and in individual cases within each series). It is assumed that on subjecting the soil to drying there is a gradual passage of some of the nitrogen of the hydrolysable protein fraction into hydrolysable nitrogen form, while concurrently some of the latter is passing into the ammoniacal and nitrate form, *i.e.* that increase in the ammoniacal and nitrate nitrogen occurs *via* the hydrolysable nitrogen. In the samples from the cotton experiments for 1936 and 1937 the change from the hydrolysable nitrogen to the ammoniacal and nitrate form has obviously been taking place at a greater rate than the formation of fresh hydrolysable nitrogen. The amount of the latter has on the average actually become slightly reduced on storage, although some must have been formed because the increase in ammoniacal and nitrate nitrogen is greater than the reduction in the hydrolysable nitrogen. In the case of the samples from the three other series of experiments there have been (on the average) increases in both forms of the available nitrogen, so that the percentage increase in the total is much greater. Similar differences in behaviour exist between individual samples of any one series both as regards the nature of the changes and the amounts of nitrogen involved. The suggested explanation of these differences, as mentioned above, may lie in part in the length of time during which the land had lain fallow prior to being sampled and in the treatment which it had received during that period. These might be reflected not only in the total quantity of available nitrogen present but also in the ratio of the ammoniacal and nitrate nitrogen to the hydrolysable. On storage in the laboratory further increase in the available nitrogen would then proceed according to the stage already reached in the field. This point is being further investigated in connection with the incubation experiments to which reference has already been made.

In referring to increases in the ammoniacal and nitrate fraction during *sharaqi* there is, of course, no question of increase in actual nitrate. Ammoniacal and nitrate nitrogen were separately determined on the layers of four profiles from the 1937 cotton experiments immediately after sampling and again after storage in the laboratory for six months. Parallel determinations of the hydrolysable nitrogen were also made. The results are averaged in Table 8B. They again show, as for the other 1937 samples, a slight reduction in hydrolysable nitrogen during storage. The increase in the ammoniacal and nitrate nitrogen fraction is seen to be due solely to the increase in the ammoniacal nitrogen, the amount of nitrate remaining unaltered.

cultivation with the ordinary native plough. These had the remarkable result that wheat grown on land ploughed by tractor was very badly affected by black stem rust while that grown on land cultivated in the ordinary way was scarcely affected, the yield of grain per feddan being as a consequence very much reduced in the former case. The relevant details of the trials are summarised in Table 9.

TABLE 9.—SAKHA TRACTOR TRIALS, 1928–1929

Method of ploughing	Sharaqi watering	Time of ploughing	Watering for land cultivation	Date of sowing	Area in feddans	Yields / feddan	
						Grain in Ardebs	Straw in Himls
Tractor	—	July 1928 (dry)	1–10 1928	24/10–14/11	335	2·70	4·76
Beladi	1–8–1928	Aug. 1928	1–10 1928	5/11–17/11	800	5·98	4·75

The land on which the trials were conducted was *sharaqi* all summer after berseem, and the only difference in treatment between the two areas, apart from the method of ploughing, lay in the fact that the land ploughed by the native plough had to receive a *sharaqi* watering in August.*

Direct trials on the effect of *sharaqi* watering were made in the following year. They are summarised in Table 10.

TABLE 10.—SAKHA WHEAT TRIALS, 1929–1930

Treatments	Area of strip in feddans	Watering for land cultivation	Dates of sowing	Yield in Ardebs/feddan	Average weight of 100 grains	Rust attack
					gm.	
A	23	28–9–1929	20–23/10	1·73	2·35	Highest
B	24	,,	24–27/10	2·10	2.24	Less than A
C	23	,,	23–27/10	3·25	3·24	,, ,, B
D	26	—	25–28/10	4·20	3·52	very slight

A—*Sharaqi* all summer—unploughed.
B— ,, ,, —ploughed dry on 2/7 and 19/8.
C— ,, watering on 5/8—then ploughed on 19/8.
D—Ploughed on 29/6 and flooded 30/8–3/10

The fine plants of wheat grown on land left dry all summer and ploughed dry were again very badly attacked by rust and gave a low

* Without this watering to soften the ground it is impossible to use a *beladi* (native) plough on *sharaqi* land.

yield, while on those grown on the land flooded from August onwards the attack was slight and the grain yield as a consequence more than double in spite of their being much smaller plants.

Similar trials were made with maize at Giza in 1930 and 1931 on land left *sharaqi* after berseem and after wheat. The land was marked out in strips and alternate strips given a *sharaqi* watering in the month of June. This watering apart, treatment of the strips was uniform except that in 1930 three sowing dates were employed. The details and results of these maize trials are given in Table 11. With the exception of the first sowing date in 1930 the maize grown on the strips left unwatered in June gave consistently higher yields than that grown after a *sharaqi* watering.

TABLE 11.—SHARAQI EXPERIMENTS WITH MAIZE AT GIZA

(a) *1930 experiment*
(Plot size = 64 × 21 m.)

Plot No.	Date of sharaqi watering	Date of watering for land cultivation	Date of sowing	Date of cutting	Yield in ardebs/feddan
A^1	—	10/7	17/7	15/11	10·00
B^1	26/6	—	17/7	15/11	12·43
A^2	—	17/7	31/7	3/12	14·30
B^2	26/6	17/7	31/7	3/12	10·60
A^3	—	31/7	14/8	17/12	13·42
B^3	26/6	31/7	14/8	17/12	9·10

(b) *1931 experiment*

Plot No.	After berseem, plot size = 64×21 m.	Plot No.	After wheat, plot size = 64×18·75 m.
A_1	10·48	A_4	8·70
B_1	8·35	B_4	7·28
A_2	9·77	A_5	6·97
B_2	8·12	B_5	5·91
A_3	12·14	A_6	6·52
B_3	9·88	B_6	5·90
		A_7	6·34
		B_7	5·41

All "A" plots remained *sharaqi* until the cultivation watering on the 15th July.

All "B" plots received a *sharaqi* watering on the 21st June as well as the cultivation watering on the 15th July.

Date of sowing the same for all plots : 1st August.

Date of cutting : 14th November.

Yields are given in ardebs per feddan.

These observations are explained as follows : It has been shown above that the effect of a period of *sharaqi* is to increase the readily available nitrogen compounds in the scil. It is also known (*e.g.* Prescott, 1920 *b*) that on remoistening such soils there are marked increases in bacterial numbers and in production of nitrate, as compared with the same soil kept continuously in the moist condition. This must now be considered as being due not to any partial sterilisation effect but merely to the fact that the drying has increased the supply of readily decomposable nitrogenous organic compounds. Once the supply of these has been exhausted it may be supposed that a period of nitrogen assimilation will set in —an indication that this can take place is afforded by the incubation experiments previously described. Assimilated nitrogen will take the form in part of resistant protein which will only slowly again become available. The watering of the land during *sharaqi* at Sakha and Giza resulted in a reduction in available nitrogen in the manner described. This was directly reflected at Giza in a lowered yield of maize on the land so treated. At Sakha the additional available nitrogen in the land left dry during the whole of the *sharaqi* period was sufficient in both years to cause so lush a growth of straw as to render it particularly susceptible to attack by rust. The 1930 experiment with maize at Giza affords the interesting additional suggestion that for marked loss of available nitrogen to occur through the watering of *sharaqi* land, at least a month should elapse between the breaking of the *sharaqi* and the planting of the succeeding crop. At the earliest sowing date (the 17th July) the difference is actually in favour of watering the land on the 26th June.

Two further *sharaqi* experiments have been carried out with cotton at Qous near Luxor in 1932 and 1934 on land on which berseem had been fed off to cattle. The treatments included added nitrogen so as to afford direct information on the amount of available nitrogen involved. The lay-out of these experiments took the form of six blocks, three of which were watered before ploughing and three ploughed dry. Each block contained sixteen plots 1/40th feddan in area arranged in the form of a latin square to which nitrate was applied at thinning at the rate of 0, 1, 2 and 3 sacks* per feddan, there being therefore twenty-four observations on each level of nitrogen, twelve on land ploughed dry and twelve on land ploughed after a watering. There was about a month's interval between the ploughing-watering and the planting of the crop. The results are given below in Table 12 and those of the 1932 experiment illustrated in Figure 4.

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* One sack of nitrate or 1N means a 100 kilos of nitrogenous fertiliser containing $15\frac{1}{2}$ kilos of nitrogen.

TABLE 12.—SHARAQI EXPERIMENTS WITH COTTON AT QOUS*

Treatments	Watered before ploughing		Ploughed dry		Date of sowing	Dates of picking
	Yield in kantars per fed.	% of crop at 2nd picking	Yield in kantars per fed.	% of crop at 2nd picking		
1932 Experiment (Variety : Giza 7)						
No manure	6·98	22·9	7·39	27·9	15/3	22/8 13/9
1 N	7·38	26·7	7·39	31·4		
2 N	7·48	30·1	6·73	36·5		
3 N	7·03	34·1	6·96	39·1		
1934 Experiment (Variety : Giza 3)						
No manure	4·85	5·8	5·29	7·3	22/3	1/9 17/9
1 N	5·99	5·6	6·64	8·5		
2 N	6·73	6·6	7·18	9·5		
3 N	7·31	6·8	7·96	11·9		

The nitrogen status of the land on which the 1932 experiment was carried out was so high that positive effects of added nitrogen on yield were small. The results at the same time show very consistent trends. On the land watered before ploughing the application of one sack increased the yield and depression does not occur until the third sack is reached. The cotton on the land ploughed dry on the other hand gave the maximum yield without any application of nitrogen while depression was caused by the second sack. The reality of these differences are confirmed by the figures for the proportion of the crop obtained at the second picking. These are consistently higher with the cotton grown on the land ploughed dry and are an expression of the fact that it contains more readily available nitrogen than the land watered for ploughing. The reduction in the amount of available nitrogen in this case can be seen from Figure 4 to amount to the equivalent of rather more than one sack (100 kilos) of nitrogenous fertiliser per feddan.

* We are indebted to Dr. Zaki Mikhail of Luxor for the facilities for carrying out these experiments.

The 1934 experiment was carried out on land, the nitrogen status of which is known to be much lower. Both on the watered and unwatered land yield effects from the nitrogen applications are correspondingly greater, but again the consistent differences between the two sets of figures confirm the fact that a pre-ploughing watering given a month before sowing has reduced the available soil nitrogen. Had the interval between the ploughing-watering and sowing been longer it is probable that the reduction in yield would have been greater and equally had it been shorter there would have been no measurable difference from the unwatered land. Further experiments on this question are being carried out.

In conclusion, as has already been pointed out in the introduction, these *sharaqi* effects are not confined to Egypt. A reduction in the available soil nitrogen as a consequence of the reactions described may easily, for example, in part account for the finding of E. M. and F. Crowther (1935) that cotton yields in the Sudan Gezira are negatively correlated with early —May and June— rainfall.

Summary of Part II

(1) The estimation of available nitrogen in Egyptian soils has been attempted by the method of incubation. This has given interesting results but the method is too cumbrous for use on a large scale.

(2) In order to make an estimate of the mobilisable nitrogen in addition to the ammoniacal and nitrate nitrogen, recourse is had to heating the soils with dilute sulphuric acid. The additional fraction so measured is termed hydrolysable nitrogen. The total of the ammoniacal, nitrate and hydrolysable nitrogen is called the available nitrogen.

(3) The amount of the available nitrogen is primarily determined by the total nitrogen ($r = + 0{\cdot}618$) and secondarily by the duration and intensity of the drying conditions to which the soil has been subjected. The immediate reserve of nitrogen of importance for the supply of available nitrogen is the hydrolysable protein.

(4) The course of the increases and changes in the amount and nature of the available nitrogen have been followed in the field and in the laboratory.

(5) It is shown from field trials and experiments that a variable part of the increased available nitrogen resulting from a *sharaqi* or a period of drying may be lost if the *sharaqi* is broken by an irrigation too soon before the planting of the succeeding crop. The loss is *presumed* to occur through assimilation by micro-organisms.

PART III

PRACTICAL APPLICATION OF THESE STUDIES WITH PARTICULAR REFERENCE TO WHEAT

The best available illustration of practical application is found in the manurial experiments with wheat carried out by the Agronomic Section during the seasons 1935–1936 and 1936–1937, and still being continued. Four levels of nitrogen are employed in these experiments and two levels of superphosphate, giving in all eight treatments. The lay-out is in the form of six randomised blocks with plot size 1/40 feddan so that the total area involved in each experiment is 1 1/5 feddans. The soil in each experiment is sampled and analysed for available nitrogen in the manner already described in Part II of this Bulletin. There were twenty-four of these experiments in 1935–1936, soil samples being taken from twenty-one; and twenty-seven for 1936–1937 of which the soil was sampled in all but two. The total fifty-one experiments were carried out at twenty-seven localities, *i.e.* twelve localities were common to both seasons. The centres for the the experiments are (as also with cotton, maize and barley) very well distributed throughout the country, extending from Mataana (Qena Province) in the south to the north of the Delta.

The total correlation coefficients which have been calculated between the grain and straw yields and grain/straw ratios of the control plots in these experiments, and the various possible combinations of the ammoniacal and nitrate nitrogen and the hydrolysable nitrogen, taken separately and together, are presented in Table 13, the results for the two seasons being treated separately. The main features of interest are briefly summarised below, full discussion being reserved for a separate publication on the growth and manuring of wheat.

Ammoniacal and nitrate nitrogen is effective mainly on the straw and is connected with the grain only because there was a strong association between the grain and the straw on the control plots in both seasons. Hydrolysable nitrogen on the other hand is effective mainly on the grain. There are not enough observations as yet to warrant a positive assertion but when these do become available it will probably be found that all of the ammoniacal and nitrate nitrogen in the whole profile, plus the composite surface sample, gives the best estimate of nitrogen of importance for the straw. Similarly that the hydrolysable nitrogen in the composite surface sample and at least the top fifty centimetres of the profile should be taken into account when considering the grain. From the point of view of quantity of nitrogen the available nitrogen in the composite surface samples is

TABLE 13.—

	Control plot yields of grain	
	1935–36	1936–37
Ammoniacal plus nitrate nitrogen in C.S.S.	—	—
,, ,, ,, ,, in A + C.S.S. ...	—	—
,, ,, ,, ,, in A + B + C.S.S.	—	—
,, ,, ,, ,, in profile + C.S.S.	+·719 (18)	+·480 (22)
,, ,, ,, ,, in profile	+·672 (18)	—
Hydrolysable nitrogen in C.S.S.	+·315 (20)	+·420 (22)
,, ,, in A + C.S.S.	+·479 (20)	+·464 (22)
,, ,, in A + B + C.S.S.	+·533 (20)	+·473 (22)
,, ,, in A + B + C + C.S.S. ...	+·512 (20)	—
,, ,, in profile + C.S.S....	+·390 (20)	+·501 (22)
,, ,, in profile	+·353 (20)	—
Hydrolysable ammoniacal and nitrate nitrogen in A + B + C.S.S.	+·642 (21) +·778 (20)	+·478 (22) —
Hydrolysable ammoniacal and nitrate nitrogen in profile + C.S.S.	—	+·527 (22)
Hydrolysable ammoniacal and nitrate nitrogen in profile	+·649 (20) —	+·597 (22) —

NOTE.—C.S.S. = composite surface sample.

A = 0–25 cm. B = 25–50 cm. C = 50–75 cm. D. = 75–100 cm.

The number in brackets after each figure is the number of experiments on which the correlation is based. The actual number of experiments from which soil samples were taken was twenty-one in 1935–1936 and twenty-five in 1936–1937.

The correlation between ammoniacal plus nitrate nitrogen and hydrolysable nitrogen in the whole profile plus composite surface sample was r = +·013 for 18 experiments in 1935–1936 and r = —·217 for 17 experiments while in 1936–1937 it was r = +·192 for 22 experiments, *i.e.* it practically does not exist.

CORRELATIONS COEFFICIENTS

Control plot yields of grain + straw		Control plot yields of straw		Ratio grain/straw on control plots	
1935–36	1936–37	1935–36	1936–37	1935–36	1936–37
—	—	+·650 (18)	+·540 (22)	—	—
—	—	+·837 (18)	+·485 (22)	—	—
—	—	+·856 (18)	+·521 (22)	—	—
+·813 (18)	—	+·862 (18)	+·594 (22)	—·659 (18)	+·111 (22)
—	—	+·847 (18)	+·446 (22)	—·729 (19)	—
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	+·090 (20)	—
—	—	+·318 (20)	—	—	—
+·371 (19)	—	+·229 (20)	+·105 (22)	—	+·497 (22)
—	—	—	—	—	—
+·811 (20)	+·486 (22)	+·794 (20)	—	—	—
+·870 (19)	—	—	—	—	—
—	+·500 (22)	—	—	—	—
+·706 (20)	+·449 (22)	—	+·229 (24)	—	—
—	—	—	+·316 (22)	—	—

of most importance, but the steady increase in the value of the correlations as more and more of the nitrogen in the lower depths of the soil is included will probably prove to be significant.

The two seasons offered a marked contrast in that the months of December 1935 and January 1936 were unduly warm while December 1936 and January 1937 were abnormally cold. The natural consequence of this is demonstrated by the figures in the table which show that ammoniacal and nitrate nitrogen was much more effective for straw production in the warmer season of 1935–1936. The best estimate of ammoniacal and nitrate nitrogen for straw production on the control plots in both seasons is, as has been seen, that contained in the whole profile plus the composite surface sample, the respective correlation coefficients being $r = +0{\cdot}862$ and $r = +0{\cdot}594$. The difference between the Z values works out at $0{\cdot}6163 \pm 0{\cdot}3454$ and as it is less than twice the standard error it is barely significant ($P = 0{\cdot}05$). Taken in conjunction with the consistent nature of all of the other differences (not reported here) between the two sets of experiments the finding is evidently a real one. The average available nitrogen content of the soils of the experiments was roughly the same in both seasons but was more effective for straw production in 1935–1936 owing to the higher temperatures experienced in the early part of the season—so much so that in the outstanding cases of three experiments conducted after berseem the maximum yield was attained without the addition of fertiliser.

A further feature of interest here, and again arising in part from these seasonal differences in temperature, lies in the grain/straw ratios of the control plots. This ratio was (*see* Table 13) negatively associated with the ammoniacal and nitrate nitrogen in the profile in 1935–1936 ($r = -0{\cdot}729$) and positively with the hydrolysable nitrogen in the profile and composite surface sample in 1936–1937 ($r = +0{\cdot}497$). The practical importance of the difference is considerable because in the season 1935–1936 the increase in grain yield from added nitrogen was more strongly associated with high grain/straw ratio on the control plots than with anything else ; but not with maximum grain production. That is to say that in 1935–1936 fertiliser nitrogen was most effective in *increasing the grain* on soils in which the initial amount of ammoniacal and nitrate nitrogen and its ratio to the hydrolysable nitrogen were both low. (It has been seen that the hydrolysable nitrogen is effective mainly on the grain.) In 1936–1937 on the other hand, when the ammoniacal and nitrate nitrogen initially present in the soils was much less effective for straw production, and grain/straw ratios as a consequence were much higher, a given amount of fertiliser was much more efficient in increasing the grain. Higher yields of grain (and lower yields of straw) were accordingly experienced in 1936–1937 than in 1935–1936 taking the average of the experiments as a whole. It would therefore be very desirable to have some control (of the same nature as that exercised by the temperatures of the growing season) over the amount of ammoniacal and nitrate nitrogen initially present and also to know its ratio to the hydrolysable nitrogen.

Physical conditions in the soil

When calculating the correlation coefficients presented in Table 13 deliberate omission was made of individual results which badly upset a relationship (the number so omitted can be seen from the table). Each of these cases forms the basis for further investigation. For example the Itai-el-Baroud experiment of 1935–1936 in spite of a high content of ammoniacal and nitrate nitrogen in the composite surface sample, gave an unduly low control plot yield. The results of the analysis of the water extract of the soil are given in Table 14, where they can be compared with those obtained on the soil from the experiment at Gimmeiza carried out in the same season where the available nitrogen acted in a straight forward manner.

TABLE 14.—ANALYSES OF SOILS FROM GIMMEIZA AND ITAI-EL-BAROUD 1935–1936 WHEAT EXPERIMENTS

Depth	% T.S.S.	Mgm. equivalents per cent of the air-dried soil					p.p.m.	
		CO_3	HCO_3	Cl	SO_4	Ca	NH_3-N + NO_3-N	H.N.
Gimmeiza Experiment								
Control plot yield { grain 7·39 ardebs/feddan; straw 12·92 himls/feddan								
C.S.S.	0·29	—	2·0	1·5	0·6	1·3	47·0	17·0
0– 25cm.	0·21	—	2·0	0·3	0·4	0·7	27·3	24·1
25– 50 „	0·23	—	2·0	0·5	0·5	0·4	16·2	16·4
50– 75 „	0·25	—	2·3	0·7	0·8	0·4	10·3	17·7
75–100 „	0·23	—	2·0	0·7	0·6	0·3	7·6	14·4
Itai-el-Baroud Experiment								
Control plot yield { grain 2·83 ardebs/feddan; straw 3·23 himls/feddan								
C.S.S.	0·53	—	3·1	3·4	1·0	2·6	62·9	18·1
0– 25cm.	0·35	—	3·7	1·3	0 6	1·2	8·9	15·1
25– 50 „	0·43	—	3·7	2·3	1·1	1·1	5·9	15·9
50– 75 „	0·58	—	3·5	3·8	2·1	1·3	6·4	13·2
75–100 „	0·61	—	3·2	4·5	2·7	1·3	6·9	11·7

The figures for the Gimmeiza soil are what would normally be obtained on any fertile Egyptian soil, while those for the soil from Itai-el-Baroud are quite abnormally high. Unusual amounts of bicarbonate and other salts should not, of course, necessarily be regarded as being in themselves the harmful factors. They are frequently merely the reflection of the much more important fact that the physical conditions in a soil are bad, *i.e.* that movement of water and air is too much restricted to allow of easy root penetration. When growth is thus restricted the influence of the available nitrogen will naturally be less than in more normal soils. This example of the importance of physical conditions is rather extreme, but it does show that any estimate of available nitrogen should be qualified by some expression for the physical conditions. The Itai-el-Baroud soil would be classified in common parlance among farmers as being rather " weak " (*ard daifa*) and the Gimmeiza one as being " strong " (*ard qawia* or *shedidah*).

Experiments with Cotton

No success such as has been demonstrated above for wheat, has been obtained so far in correlating yield in the cotton experiments with estimates of available nitrogen made on soil samples taken at sowing time. There are two possible reasons for this :—

(*a*) It has been seen above that the efficiency of available soil nitrogen for wheat varies significantly from season to season according to climatic conditions. The cotton crop in Egypt is known to be at least as sensitive to climatic conditions and more sensitive to water strain (*i.e.* to the physical conditions in the soil) than wheat. Consequently it may well be true that these factors, and others such as sowing date are so dominant in their effect as to obliterate any such yield differences as might be occasioned by mere variation in the amount of available soil nitrogen.

(*b*) The other possibility is that the estimate of available soil nitrogen has been made at the wrong time, or even that the method of making the estimation is not the correct one. The observations recorded in Part II of this Bulletin on incubation experiments in the laboratory, and on *sharaqi* experiments in the field suggest that this is quite a possibility. Incubation experiments in the laboratory are impracticable because of the labour involved by such a large number of samples ; as an alternative method the soils of the manurial experiments were sampled twice this year (1938), at sowing time, and again at thinning time, which is when any nitrogenous fertiliser given to cotton is usually applied. The results have not yet been fully worked out but interesting changes can at least be shown to have taken place in the amount and constitution of the available nitrogen during the interval between these two times of sampling.

Summary of Part III

The correlation coefficients calculated between various estimates of available soil nitrogen and control plot yields of grain and straw, and grain/straw ratios in the wheat experiments for the two seasons 1935–1936 and 1936–1937 show :—

(*a*) That ammoniacal and nitrate nitrogen is effective mainly on the straw, and that hydrolysable nitrogen acts mainly on the grain.

(*b*) That all of the available nitrogen down to the depth of one metre is probably of importance to the wheat plant.

(*c*) That there was a significant difference in the efficiency of the ammoniacal and nitrate nitrogen for straw production in these two seasons for climatic reasons.

(*d*) That high return in grain from added fertiliser is associated with high grain/straw ratio, the latter being in turn the reflection of the findings under (*c*) and (*a*).

(*e*) That the physical properties of a soil should be taken into account in considering any estimate of its content of available nitrogen.

The absence of similar success so far in dealing with the cotton experiments may be due to two things :—

(1) That other factors are so dominant as to obliterate any variations in yield arising from variations in the amount of available nitrogen, *or*

(2) That the method of estimating the available nitrogen is unsuitable ; or even, that the time at which the soils have been sampled for the estimation is wrong.

Acknowledgments

It is obvious that work of the nature and scope reported on in this Bulletin can only result from the co-operative effort of a number of workers. It is a pleasure to record the wholehearted co-operation of Mahfuz Rizk Eff., Mohammad Ahmed Ali Eff., Ahmed Mukhtar Eff., Dr. Ahmad Shalabi, Wahba Saleh Eff., Mohammad Kamal Mohammad Eff., Mohammad el-Kadi Eff., and Zaki Sawiris Eff., all past or present members of the Chemical Section. The field experiments, apart from the few on *sharaqi* effects, are all conducted by the Agronomic Section of the Ministry of Agriculture.

Acknowledgment must also be made to Dr. W. L. Balls, Mr. H. A. Hancock and to the Chief Chemist, Dr. W. T. H. Williamson, for reading the manuscript and for helpful criticism.

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Appendix I

Methods of analysis for organic carbon and total nitrogen

(a) *Organic Carbon.*

A wet combustion method was used which corresponded closely in its details to the Leningrad (*c*) method as given in the " first report of the organic carbon committee " of the International Society for Soil Science (E. M. Crowther, 1935). According to that report this method gave approximately full recovery of organic carbon as compared with the dry combustion method. No determinations have been made by the latter method to check the wet combustion figures. Calcium carbonate is always present in Egyptian Soils (in amount on the average of 2–3 per cent) and as pointed out in the report referred to, its presence unavoidably interferes with the accurate determination of organic carbon. Separate (gravimetric) estimations of inorganic carbon were made on all samples and its amount deducted from the total carbon figures obtained by wet combustion. The figures for calcium carbonate are not included in the tables. They present features of considerable interest and will be dealt with in a separate publication.

(b) *Total Nitrogen.*

Bal's (1925) modification of the Kjeldahl process of estimating the total nitrogen in the soils was found to be necessary if a colourless mixture was to be obtained at the end of the digestion. The actual increase in the amount of total nitrogen found as a result of the modification was however small. In the method as used 10 gm. of soil, 5 gm. potassium sulphate, and 0·2 gm. copper sulphate were introduced into a Kjeldahl flask and shaken up with 25 ml. of distilled water. Half an hour later 30 ml. concentrated sulphuric acid were added and the mixture allowed to stand over night. The following morning it was heated gently during 15 minutes and then strongly during 2 1/2 hours or half an hour after the contents of the flask had become clear. The contents were then transferred to a distillation flask and the ammonia distilled into standard acid in the usual way. Prolongation of the period of heating in the digestion flask beyond that mentioned did not result in any further increase in the total nitrogen.

In the case of the determination both of organic carbon and total nitrogen duplicate estimations were always made and the estimation repeated until concordant results were obtained within certain limits. These limits were $\pm$ 0·002 per cent in the case of total nitrogen and $\pm$ 0·04 per cent in the case of organic carbon, although in both cases agreement was generally well within the limits.

TABLE 1.—THE PERCENTAGES OF TOTAL NITROGEN, ORGANIC CARBON, α HUMUS AND NITROGEN IN THE HUMUS AND THE C/N RATIO OF NINETEEN PROFILES (1931 FIGURES)

Locality	Soil No.	Depth	% Total nitrogen	% Organic carbon	Ratio C/N	% α Humus	% N in α humus
		cm.					
Giza ...	18	0– 20	0·081	0·87	10·7	0·49	3·13
	19	20– 40	0·050	0·61	12·2	0·39	3·74
Giza ...	24	0– 20	0·071	0·80	11·3	0·43	3·27
	25	20– 40	0·029	0·34	11·7	0·19	3·02
Giza ...	29	0– 15	0·107	1·10	10·3	0·63	3·33
	30	15– 35	0·055	0·59	10·7	0·36	2·91
Giza ...	35	0– 15	0·105	1·13	10·8	0·62	3·30
	36	15– 30	0·061	0·67	11·0	0·38	3·11
Beni Saleh	48	0– 20	0·072	0·77	10·7	0·39	3·16
	49	20– 50	0·041	0·48	11·7	0·26	2·58
	50	50– 95	0·026	0·33	12·7	0·20	2.20
	51	95–105	0·023	0·43	18·7	0·21	2·00
Gimmeiza	128	0– 20	0·094	0·98	10·4	0·57	3·39
	129	20– 40	0·059	0·69	11·7	0·37	2·95
	130	40– 60	0·036	0·45	12·5	0·27	2·50
Giza ...	156	0– 10	0·086	0·86	10·0	0·57	3·26
	157	10– 20	0·079	0·91	11·5	0·50	3·23
	158	20– 30	0·052	0·58	11·2	0·33	2·98
	159	30– 40	0·039	0·51	13·1	0·30	3·15
Nag-Hammadi	183	0– 22	0·068	0·76	11·2	0·53	3·00
	184	22– 55	0·056	0·65	11·3	0·50	2·55
	185	55– 85	0·045	0·65	14·4	0·47	2·34
Siberbai ...	222	0– 20	0·099	1·05	10·6	0·62	2·97
	223	20– 40	0·081	0·78	9·6	0·38	3·16
	224	40– 60	0·058	0·58	10·0	0·30	3·14
	225	60– 80	0·050	0·51	10·2	0·26	3·24
Difra ...	228	0– 20	0·053	0·88	16·6	0·48	2·57
	229	20– 40	0·062	0·70	11·3	0·44	3·09
	230	40– 60	0·049	0·62	12·7	0·39	2·55
	231	60– 80	0·042	0·57	13·6	0·39	2·25

Locality	Soil No.	Depth	% Total nitrogen	% Organic carbon	Ratio C/N	% α Humus	% N in α humus
		cm.					
Qaraqis ...	236	0– 20	0·106	1·05	9·9	0·48	2·85
	237	20– 40	0·048	0·58	12·1	0·30	2·29
	238	40– 60	0·035	0·45	12·9	0·26	3·59
	239	60– 80	0·035	0·46	13·1	0·24	3·03
	240	80–100	0·033	0·53	16·1	0·33	2·79
Qous ...	301	0– 20	0·056	0·70	12·5	0·48	3·69
	302	20– 40	0·048	0·64	13·3	0·47	2·43
	303	40– 60	0·046	0·57	12·4	0·37	2·67
	304	60– 80	0·038	0·49	12·9	0·31	2·74
	305	80–100	0·033	0·48	14·5	0·34	2·10
Qous ...	307	0– 15	0·040	0·57	14·3	0·40	2·30
	308	15– 30	0·024	0·32	13·3	0·22	2·37
	309	30– 45	0·015	0·16	10·7	0·08	3·90
	310	45– 50	0·041	0·54	13·2	0·39	2·25
Qous ...	314	0– 20	0·049	0·60	12·2	0·40	2·87
	315	20– 40	0·045	0·64	14·2	0·40	2·60
	316	40– 60	0·044	0·58	13·2	0·41	2·43
El-Azab ...	319	0– 20	0·090	0·89	9·9	0·50	2·78
	320	20– 40	0·070	0·63	9·0	0·41	3·01
	321	40– 60	0·043	0·56	13·0	0·36	3·89
	322	60– 80	0·040	0·65	16·3	0·44	2·34
	323	80–100	0·034	0·56	16·5	0·38	2·60
El-Kufur...	377 A	0– 20	0·082	0·86	10·5	0·56	3·33
	377 B	20– 40	0·051	0·61	12·0	0·39	3·01
	377 C	40– 60	0·044	0·54	12·3	0·38	3·02
	377 D	60– 80	0·043	0·57	13·3	0·37	2·67
Deirout ...	385 A	0– 25	0·112	1·32	11·8	0·79	3·50
	385 B	25– 50	0·108	1·24	11·5	0·80	3·24
	385 C	50– 75	0·058	0·68	11·7	0·39	3·06
	385 D	75–100	0·044	0·54	12·3	0·37	2·63
El-Hawaslia	390 A	0– 12	0·091	0·88	9·7	0·56	3·00
	390 B	12– 37	0·060	0·66	11·0	0·45	2·66
	390 C	37– 62	0·044	0·56	12·7	0·46	2·14
	390 D	62– 87	0·046	0·60	13·0	0·46	2·25
El-Kufur...	391 A	0– 20	0·096	1·03	10·7	0·64	3·17
	391 B	20– 45	0·076	0·79	10·4	0·48	3·04
	391 C	45– 70	0·048	0·61	12·7	0·35	2·74
	391 D	70– 95	0·050	0·55	11·0	0·38	2·50

TABLE 2.—THE PERCENTAGE OF TOTAL NITROGEN AND ORGANIC CARBON AND THE C/N RATIOS OF THE TWENTY-FOUR PROFILES AND COMPOSITE SURFACE SAMPLES (C.S.S.) TAKEN FROM THE 1935 COTTON EXPERIMENTS

Locality	Soil No.	Depth.	% Total nitrogen	% Organic carbon	Ratio C/N
		cm.			
El-Shoqqa	1	C.S.S.	0·083	0·90	10·8
		0– 25	0·054	0·74	13·7
		25– 50	0·043	0·57	13·3
		50– 75	0·040	0·54	13·5
		75–100	0·041	0·53	12·9
Kafr-el-Sheikh	2	C.S.S.	0·081	0·80	9·9
		0– 25	0·075	0·79	10·5
		25– 50	0·052	0·60	11·5
		50– 75	0·043	0·54	12·6
		75–100	0·030	0·49	16·3
Sakha	3	C.S.S.	0·079	0·84	10·6
		0– 25	0·063	0·72	11·4
		25– 50	0·054	0·61	11·3
		50– 75	0·045	0·57	12·7
		75–100	0·043	0·52	12·1
Motamadiya	4	C.S.S.	0·092	1·03	11·2
		0– 25	0·078	0·75	9·6
		25– 50	0·059	0·63	10·7
		50– 75	0·043	0·44	10·2
		75–100	0·034	0·47	13·8
Gimmeiza	5	C.S.S.	0·077	0·94	12·2
		0– 25	0·065	0·75	11·5
		25– 50	0·053	0·69	13·0
		50– 75	0·048	0·63	13·1
		75–100	0·046	0·64	13·9
Miniet Ebiar	6	C.S.S.	0·088	0·96	10·9
		0– 25	0·075	0·89	11·9
		25– 50	0·062	0·70	11·3
		50– 75	0·054	0·60	11·1
		75–100	0·043	0·62	14·4
Siberbai (R.W.)	7	C.S.S.	0·076	0·73	9·6
		0– 25	0·053	0·74	14·0
		25– 50	0·045	0·64	14·2
		50– 75	0·043	0·60	14·0
		75–100	0·037	0·52	14·1

Locality	Soil No.	Depth	% Total nitrogen	% Organic carbon	Ratio C/N
		cm.			
El-Baramone	11	C.S.S.	0·095	1·21	12·7
		0– 25	0·088	0·96	10·9
		25– 50	0·062	0·72	11·6
		50– 75	0·053	0·60	11·3
		75–100	0·044	0·47	10·7
Oesh-el-Hagar	12	C.S.S.	0·101	1·10	10·9
		0– 25	0·090	1·09	12·1
		25– 50	0·061	0·77	12·6
		50– 75	0·049	0·76	15·5
		75–100	0·043	0·60	14·0
Ghorour	15	C.S.S.	0·098	1·07	10·9
		0– 25	0·082	0·89	10·9
		25– 50	0·044	0·49	11·1
		50– 75	0·035	0·44	12·6
		75–100	0·028	0·44	15·7
Shubra Hoar	17	C.S.S.	0·084	0·95	11·3
		0– 25	0·068	0·74	10·9
		25– 50	0·050	0·57	11·4
		50– 75	0·033	0·37	11·2
		75–100	0·032	0·46	14·4
El-Qattawia	20	C.S.S.	0·103	0·98	9·5
		0– 25	0·075	0·75	10·0
		25– 50	0·054	0·59	10·9
		50– 75	0·042	0·47	11·2
		75–100	0·043	0·50	11·6
El-Halawat	21	C.S.S.	0·078	0·90	11·5
		0– 25	0·067	0·84	12·5
		25– 50	0·049	0·57	11·6
		50– 75	0·041	0·47	11·5
		75–100	0·033	0·40	12·1
Kafr Atalla	22	C.S.S.	0·088	1·08	12·3
		0– 25	0·085	1·02	12·0
		25– 50	0·063	0·76	12·1
		50– 75	0·044	0·71	16·1
		75–100	0·042	0·59	14·0
Mit Gaber	23	C.S.S.	0·086	1·00	11·6
		0– 25	0·083	0·96	11·6
		25– 50	0·051	0·66	12·9
		50– 75	0·037	0·50	13·5
		75–100	0·036	0·43	11·9

Locality	Soil No.	Depth	% Total nitrogen	% Organic carbon	Ratio C/N
		cm.			
Ezbet-el-Wust	24	C.S.S.	0·084	0·99	11·8
		0– 25	0·069	0·74	10·7
		25– 50	0·038	0·38	10·0
		50– 75	0·033	0·48	14·6
		75–100	0·029	0·41	14·1
Zamzam	25	C.S.S.	0·098	1·14	11·6
		0– 25	0·077	0·88	11·4
		25– 50	0·058	0·75	12·9
		50– 75	0·044	0·57	13·0
		75–100	0·039	0·56	14·4
Itai-el-Baroud	26	C.S.S.	0·096	1·00	10·4
		0– 25	0·091	0·97	10·7
		25– 50	0·059	0·68	11·5
		50– 75	0·041	0·45	11·0
		75–100	0·034	0·47	13·8
Kufur-el-Raml	27	C.S.S.	0·082	0·82	10·0
		0– 25	0·073	0·80	11·0
		25– 50	0·055	0·68	12·4
		50– 75	0·051	0·68	13·3
		75–100	0·046	0·63	13·7
Qaha	31	C.S.S.	0·089	1·10	12·4
		0– 25	0·075	0·89	11·9
		25– 50	0·057	0·73	12·8
		50– 75	0·054	0·70	13·0
		75–100	0·049	0·68	13·9
El-Marg	32	C.S.S.	0·080	0·88	11·0
		0– 25	0·075	0·83	11·1
		25– 50	0·052	0·67	12·9
		50– 75	0·048	0·61	12·7
		75–100	0·045	0·63	14·0
Taha-el-Bisha	32	C.S.S.	0·096	1·01	10·5
		0– 25	0·091	0·90	9·9
		25– 50	0·058	0·74	12·8
		50– 75	0·053	0·70	13·2
		75–100	0·049	0·68	13·9
Mallawi	38	C.S.S.	0·099	1·07	10·8
		0– 25	0·088	0 98	11·1
		25– 50	0·054	0·63	11·7
		50– 75	0·043	0·59	13·7
		75–100	0·039	0·49	12·4

Locality	Soil No.	Depth	% Total nitrogen	% Organic carbon	Ratio C/N
		cm.			
Mataana	39	C.S.S.	0·052	0·64	12·3
		0– 25	0·044	0·49	11·1
		25– 50	0·045	0·51	11·3
		50– 75	0·035	0·47	13·4
		75–100	0·038	0·46	12·1

Appendix II

Explanation of Egyptian Weights and Measures used

1 ardeb of wheat = 150 kg.
1 „ „ maize = 140 kg.
1 himl wheat straw = 250 kg.
1 kantar of seed cotton = 315 rotls.
1 rotl = 0·449 kg. = 0·99 lb. av.
1 feddan = 4,200 sq.m. = 1·083 acres.

Govt. Press 12777-1938-1065 ex.

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service
Cotton Research Board

BULLETIN No. 229

Dibble-Sowing of Cotton
Method, Effects and Profits

BY

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(Recommended for publication by the Publications Committee of the Ministry of Agriculture, which is not, as a body, responsible for the opinions expressed in this Bulletin).

SCHINDLER PRESS — CAIRO 1939

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Price - - - - - - - - - - P.T. 6

DIBBLE-SOWING OF COTTON.

Method, Effects and Profits.

by

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and

W. Lawrence Balls, Sc.D. F.R.S.

Table of Contents.

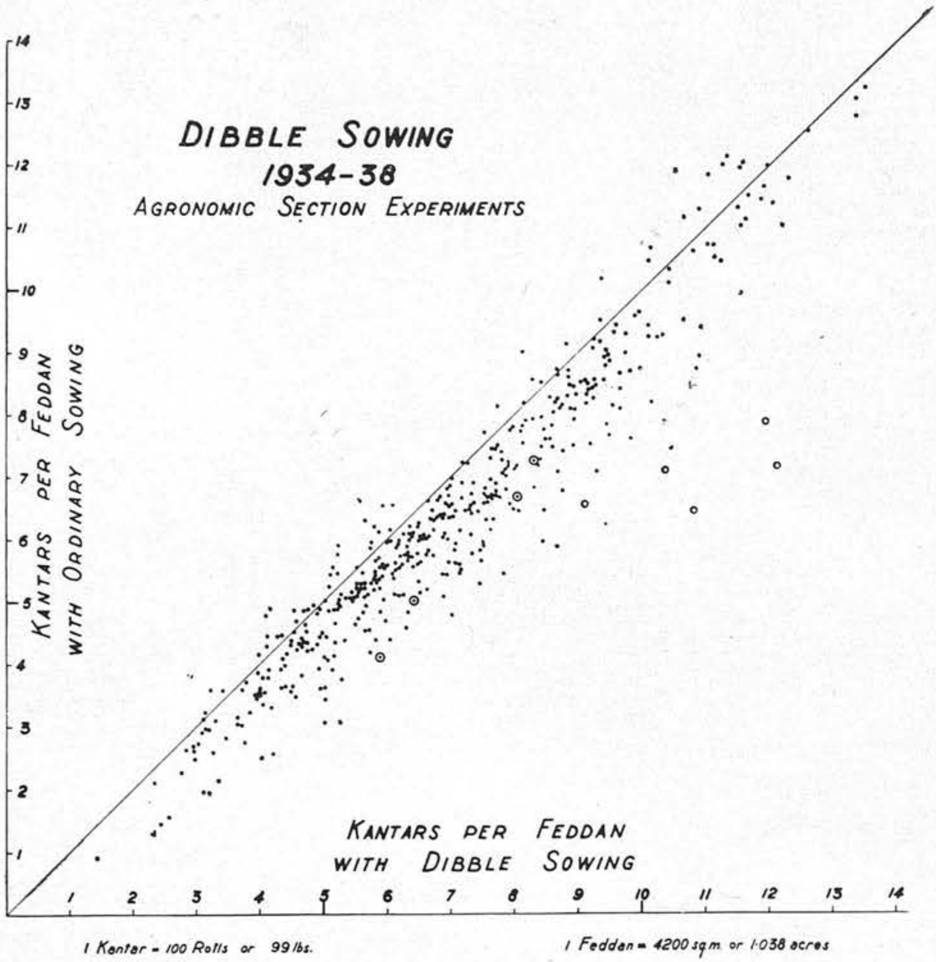

Fig. 1.— Each dot represents the average yield of five or more separate plots of dibbled cotton, if its position is read off along the horizontal scale. The same dot also shows the average yield of five more separate plots, twins of the others but sown in the ordinary way, if the position of the dot is read off along the vertical scale.

Thus, if the yield were identical in both sowing methods the dots would lie on the diagonal "line of equality", which passes through 1/1, 2/2 etc., to 14/14. When dibbling gives the bigger yield the dot lies below this line.

The comparisons were made under deliberate alterations of sowing dates and varieties, and under accidental choice of soils, waterings, and farm practices in all parts of Egypt. In several known cases the dibbling was not done correctly. The greatest advantage by dibbling in this figures is 4.90 kantars (7.18 to 12.10) and the worst disadvantage is only 1.35 kantars (11.88 to 10.50). The average advantage is 0.70 kantars.

Four dotted circles show the result of the experiment in 1931 by the Botanical Section, in which effect of dibbling on yield was first discovered.

Five open circles show the comparison of five varieties at Mataana in 1937 on soil of bad tilth, being the condition under which dibbling give its maximum advantage.

DIBBLE-SOWING OF COTTON

Method, Effects and Profit.

Introductory.

Five hundred field comparisons made by our Agronomic Section during five seasons are plotted in Fig. 1 to show the effect of dibble sowing on the total crop of an Egyptian cotton field, under all likely variations of soil, locality, variety, sowing time, irrigation, manures, etc.

Agricultural science has shown but few results which are more remarkable than this graph. The monetary cost of dibble-sowing is demonstrated by the Agronomic Section records to be little more than that of ordinary sowing, while the average yield-advantage shown in Fig. 1 is seventy rotls, or P.T. 180. This amount is not much less than the average total yield per feddan of India. The general adoption of dibble-sowing would thus add a million kantars to the Egyptian crop, at a profit of L.E. 2,000,000, even with present low prices.

We shall show that the advantage can actually be greater than a whole kantar, under proper utilization of the method, and it is now important to present the great mass of information available, so that the essentials shall be understood in any attempt by growers to utilise it. There has been no attempt to make propaganda for the adoption of the method, and with many growers there is a definite objection to the extra trouble, labour, and organization involved. But, since cotton-growing is a business proposition, we think this objection must mainly be due to incredulity; to a reasonable disbelief that such a trivial alteration in cotton-growing procedure should have such an astonishing effect. Our Fig. 1 should dissipate this incredulity.

The present account gives the history of the origin of the method, then deals with its detailed effects on the growth of the crop. For the data used in analysing the crop-behaviour we are mainly indebted to the work of Dr. J. Templeton and particularly of Mohammad Zaghloul Effendi. With the procedure well established, and the reasons for its advantage realised in broad outline, we then deal with the more strictly agricultural aspects which have been revealed by dissection and analysis of the mass of experimental data obtained by the Agronomic Section, presenting these data themselves in the Appendix.

1. Historical.

The history of dibble-sowing begins on April 8th, 1913. Twenty feddans of land attached to the "Old Lab" at Giza had been wide sown with 20,000 holes of pedigree seedlings from the strain No. 77, and the seedlings were coming up nicely after three months of worry. An office blunder had left the former tenants on this land at the time when it should have been taken over, and only by organizing most minute details had Mr. F. S. Holton been able to get the cultivation finished in time to sow the crop. Behind this seed-propagation work was the stimulus of Lord Kitchener's desire for immediate results; so we had set out to break records and looked like doing it after all. The strain "No. 77", offspring of a single plant of 1911, grown under wire gauze cages in 1912, was the backbone of our project.

In the early morning of April 8th we found these cherished seedlings dying in all directions. The land had been in market garden cultivation, we had been unable to give it any rest, and it was riddled with unsuspected mole-cricket burrows. On that morning the soil-moisture conditions had become such that the burrows had come to the surface and were running along the flank of every ridge, blindly smashing our seedlings. The numbers of crickets may be judged from the fact that we trapped 1265 of them during the next six weeks, and the rate of daily catch had not slowed down much by June. By April 11th there were not more than one thousand seedlings left, only one in twenty. How to set about resowing?

Our initial supply of "cage-grown" seed was 13 kilos, and $1^1/_2$ kilos had been kept in reserve for re-sowing. This was 15,000 seeds with which to re-sow 19,000 holes. Nor was this all good seed, on account of delayed picking to provide demonstrations for the 1912 Cotton Congress. Small amounts of pedigree seed were scraped up from the seed-files of previous years, and an emergency procedure was extemporised to ensure that every available viable seed would germinate, by placing the seed in a trough of slow-running water which washed bacteria away. Each seed as it germinated was placed on damp sand in petri dishes and carried into the field to be sown. The diary of that hectic month records every seed thus handled, ending with a total of 11,359 individual germinated seeds taken out and sown. If every one of these could be carried to maturity we should not be very far short of 20,000 plants. This was the situation which, of itself, invented dibble-sowing.

After arranging some partial protection for each hole from the crickets we proceeded as thus recorded in the diary for April 9th, one day after the disaster... "a clean hole was made by turning a small stake smoothed down, the seed dropped in, syringed down with water from a fountain pen pipette, a teaspoonful of sand dropped over it. One man followed behind watering carefully from a watering pot so as not to disturb the sand". At the end of a fortnight the last seed had been coaxed into action, and a stand of 90% with single seed sowing would have been secured apart from the mole-crickets ; even so we were able to record 5,000 plants safely established on May 15th, and the seed-propagation recōrd was broken after all.

With the original spacing of four square metres per plant enlarged to nearly ten square metres, on rich market garden soil, and with only a little pink boll-worm, there was a maximal production of seed per plant, and at the end of 1913 we ginned a ton of seed descended from a single seed sown in 1911.

The subject was then dropped for thirteen years until some correspondence in the Empire Cotton Growing Review (about soil-breaking plants to assist the emergence of the feeble cotton seedling in plant-breeding work) led to the writing of a short article on "The best field method of sowing cotton" (1), giving a detailed account of the procedure which had been followed at Giza, and pointing out the cumulative effect year by year of reduced seed-rate in the propagation of seed-stocks.

In 1927 one of the authors returned to Giza, was unfavourably impressed by the poor stand of seedlings in the breeding plots, and found that dibble-sowing (or sand-sowing, as it had unfortunately been called) was quite forgotten. Gedalla Abou El Ela Effendi was commissioned to start some direct experiments on the technique of dibbling, with the simple intention of re-introducing it as a means of saving both land and seed in cotton breeding. His subsequent publications (2) present the following conclusions : —

A. The best sowing depth (using the old type of dibble) was 22 - 34 mm. One seed per hole could give 80% stand.

B. Previous soaking of the seed was not superior to sowing dry seed. All types of dibble-sowing were more efficient than using *Hibiscus esculentus* as a soil breaker.
A preliminary damping of the soil was an improvement.
Holes with conical sides would ensure free escape of the seedling.

C. (In this third set of experiments conical dibbles of various shapes were used, making a hole 25 mm. deep, and of width suitable for the varied numbers of seeds sown in each hole).

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(1) W.L,B. : E.C.G.C. Review. II 3. July 1925.

(2) G. A. E. : Ministry of Agriculture, Egypt : 1929. Technical Bulletins No. 80 and 122.

Dibbling in dry soil followed by watering is better than sowing in damp soil without watering.

One-seed sowing gave 23% more plants than two-seed sowing.

Two seed sowing gave 18% more stand on a given area than one seed sowing.

Previous conclusions against preliminary soaking of seed, but in favour of preliminary watering of the soil, were confirmed.

D. Some later experiments showed that the use of dust from an earth road, or of Nile silt, was not quite as good as the use of sand, but only slightly inferior.

2. The Dibble.

Out of these trials we designed a simple dibble which has been widely used (Fig. 2). An egg-shaped excrescence on a flat surface makes a hole exactly one inch deep and about an inch across, this hole being surrounded by a flat surface about half an inch wide ; this exact definition of depth is quite important. It is turned in a lathe out of wood, has a blunt upper end to fit the palm of the hand and a loose strap over the back of the hand. This has lately been improved by Dr. Khalil and Mufid Eff. using a longer dibble with an angled hand grip which serves as a measuring stick for spacing the holes along the ridge, requires less stooping by the boy operative, and is much less tiring to his hand ; also the offset handle facilitates giving a little twisting movement to the dibble when it is being removed from the hole, which gives the hole a firm and sometimes almost polished surface. The usual dibble makes a hole (Fig. 3) just wide enough to allow five seeds to lie side by side at the bottom of the hole ; special dibbles, smaller or larger are only used for experimental purposes, as it is one of the essential definitions of dibble-sowing under field crop conditions that *not more than five seeds* may be used.

We shall see later that exceptional advantages follow dibble-sowing in soils of bad tilth. Such soils are conversely difficult to dibble, and there would seem to be possibilities for a dibble made in the form of a rather heavy mallet, which would pulverize the clods and make the hole in one operation.

The essentials in dibble-sowing are thus the use of a conical or egg-shaped hole, one inch in depth, containing not more than five seeds, made in soil which has previously been watered, the hole being filled up with sand or silt. The firm compressed surface of the hole (Fig. 3) wets readily by capillarity, but although the sand or silt also becomes damp it is loose-textured and does not lose water freely ; thus the sand forms a partial cover against evaporation. Further, there is but slight adhesion between

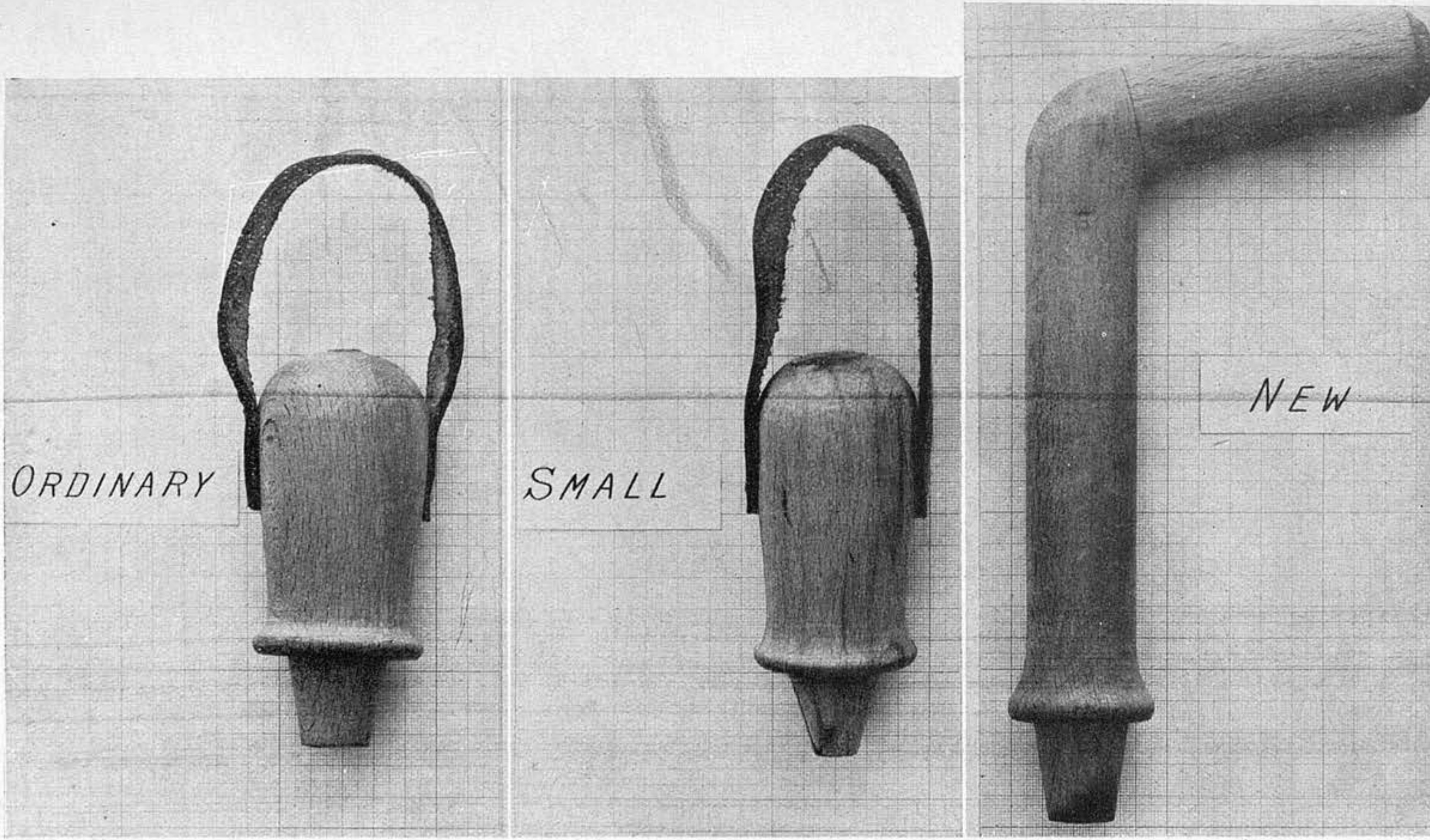
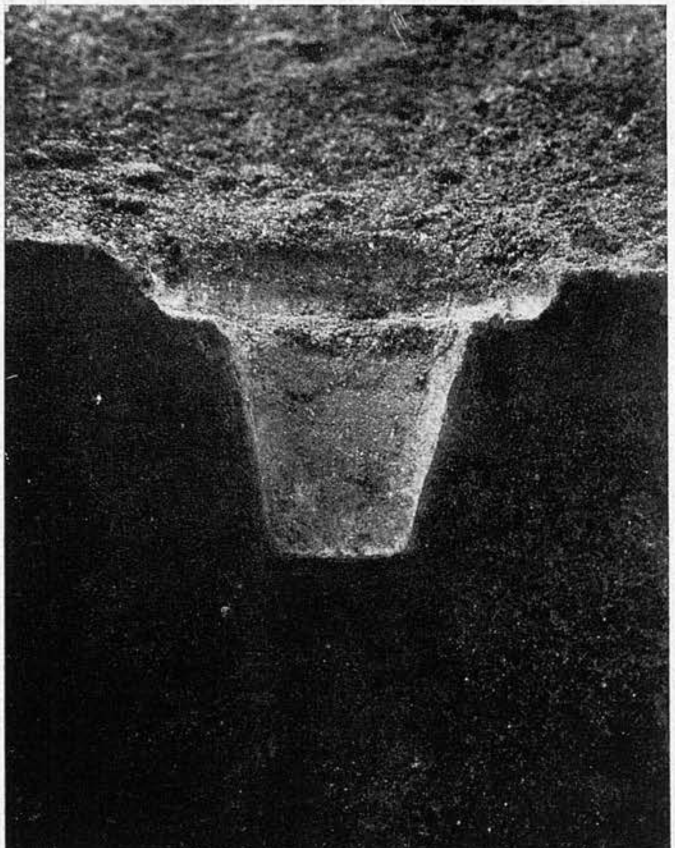


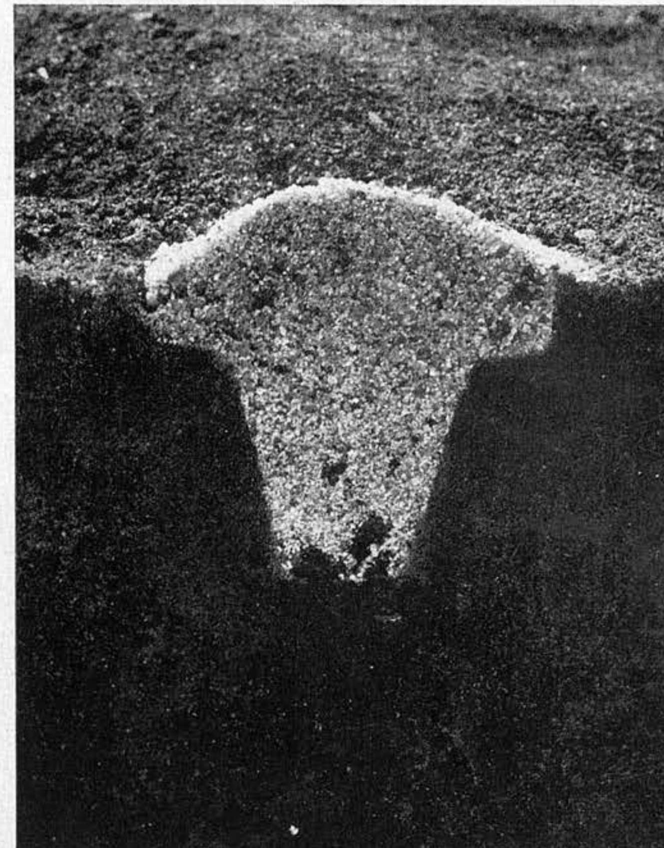
FIG. 2.—TYPES OF DIBBLE

Photographed on millimetre-sqared paper.

Fig. 3.—DIBBLE-SOWING IN SECTION

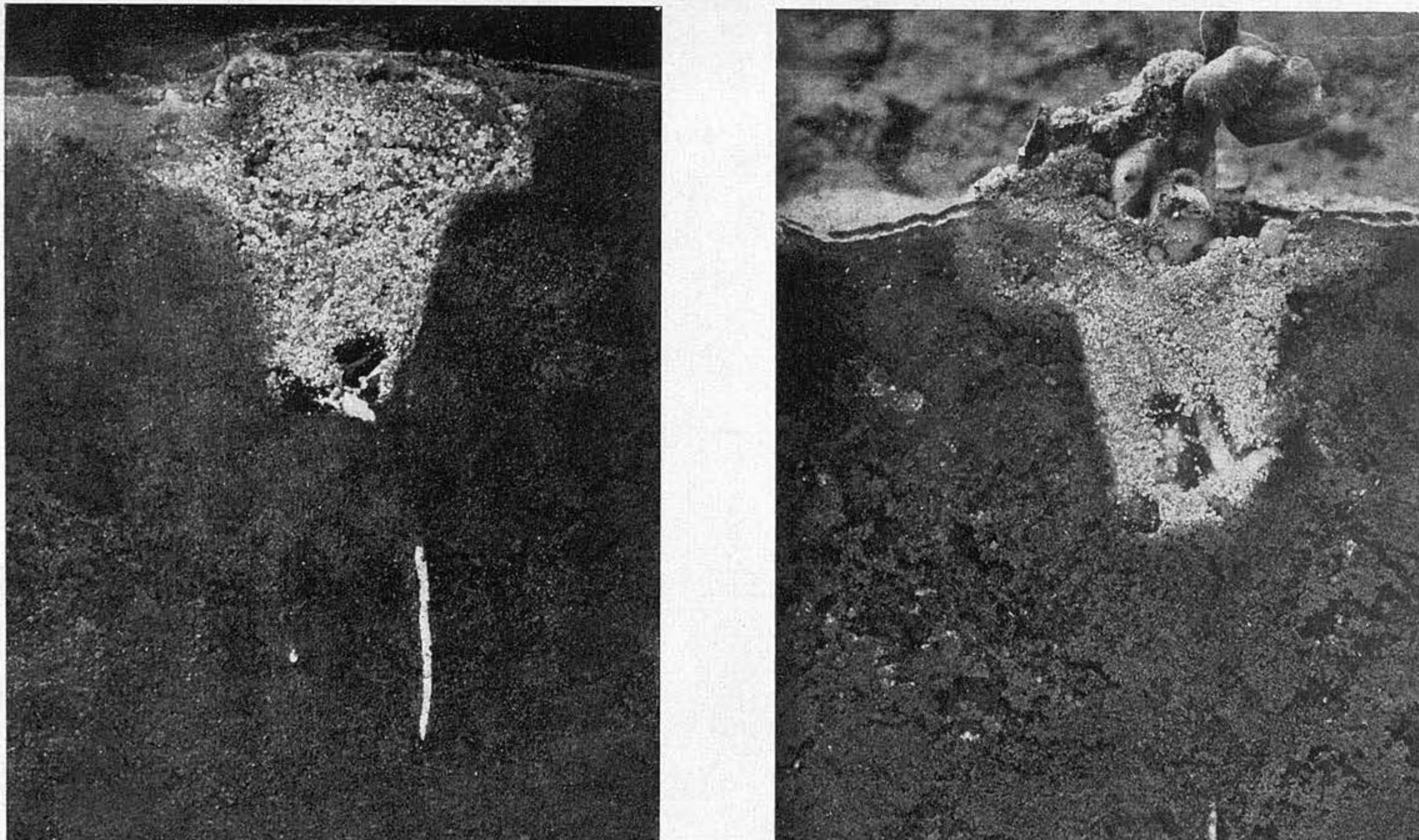


Section of a Dibbled Hole.



Seed and Sand in Hole.

Fig. 4.—DIBBLE-SOWING IN SECTION.



Roots descending.

Seed-leaves unfolding.

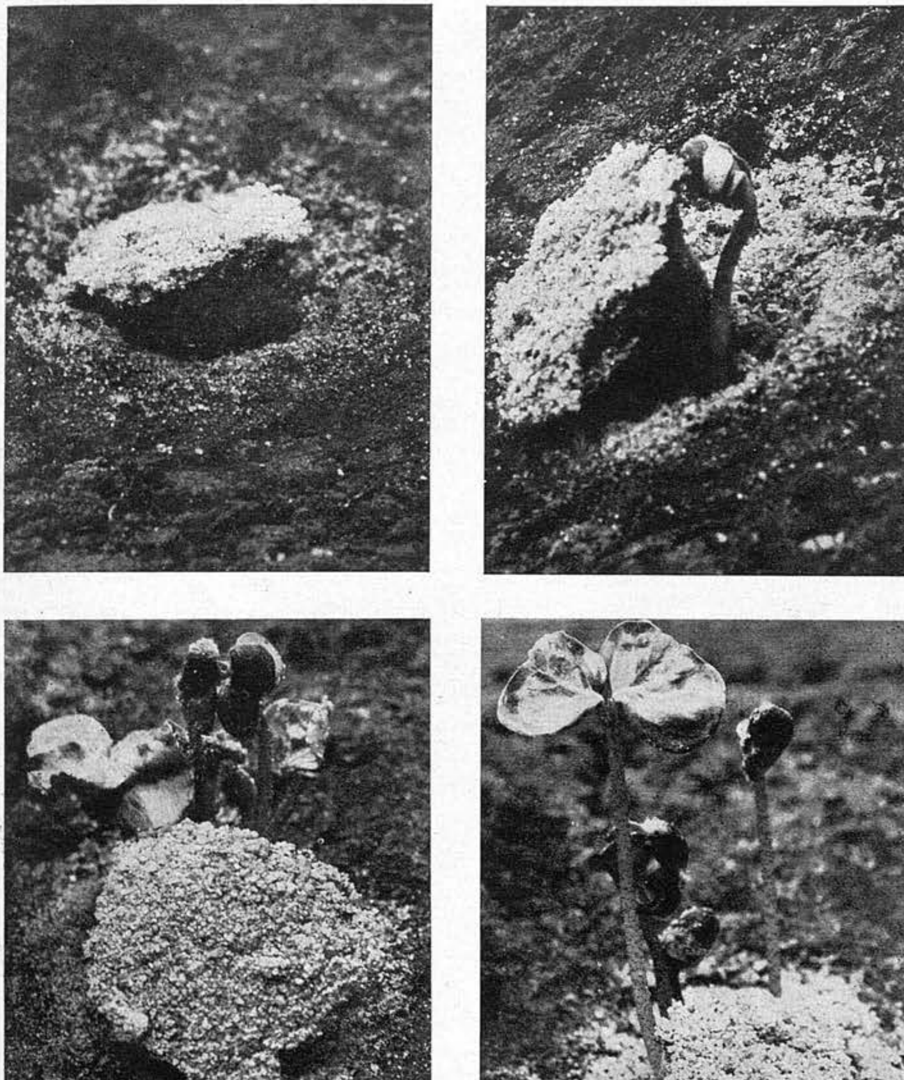
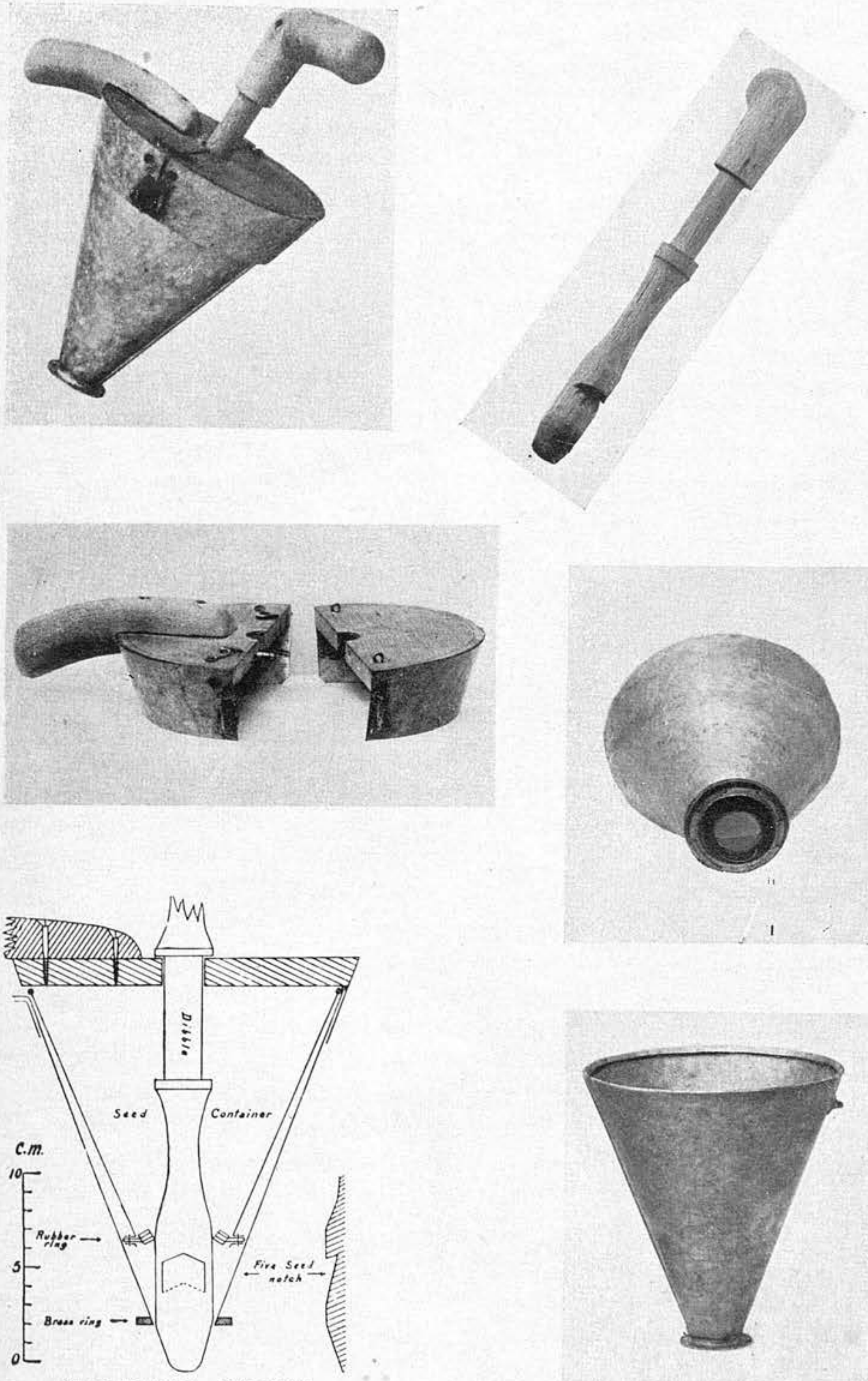


Fig. 5.—Stages in the emergence of dibbled seedlings, showing the sand lifting without breaking and the seedlings slipping past it.

FIG. 6.—MAGAZINE DIBBLE



the loose sand and the firm soil, and the form of the surface of the hole is such that they crack apart under very small pressure from below when the seed germinates (Fig. 4), and an easy passage is provided along the crack to the open air. It is curious, and illustrates the ease of the passage, that the sand very seldom crumbles, but is lifted up and sideways as a solid plug which takes a cast of the hole (Fig. 5).

Irrigation after sowing has hardly any disturbing effect on the sand cover, and ensures that it and the seed are thoroughtly wetted. It is the correct practice, and much safer than to attempt to "sow wet".

Magazine Dibble.

When we come to discuss the cost of dibble-sowing we shall find that the fundamental difficulty is not finance, but labour-shortage. The dibble requires extra boys, who may not be available. One boy can be eliminated if the act of dibbling also counts out the right number of seeds and puts them into the hole ; this can be done automatically by means of a construction well within the resources of any village craftsman.

Such a construction is illustrated in Fig. 6. It makes no pretension to be final, but it demonstrates the limiting conditions of design. It is made of wood, tin, and a piece of rubber by using a lathe, soldering iron, saw and screw driver, and might cost as much as ten piastres. It carries a pound of seed which will plant one-fortieth of a feddan, and 80 % of the holes made receive 4, 5, or 6 seeds ; occasionally it sows 7, 3, and rarely 2 seeds.

It is sufficiently robust to stand rough use, easily carried or stood down, and emptied or filled easily by unfastening one half of the lid. On opening both halves it falls into three pieces when cleaning is needed.

The leading boy using such a dibble leaves an open hole with the seed in full view. He is followed by a second boy who applies the sand or silt ; should the dibble have failed for any reason, the fact is obvious to him. A completely automatic dibble which would apply the sand also is quite feasible, but the risk of failure which would leave several ridges seedless is too serious.

But, the use of such a dibble is contingent on the removal of all lint and fuzz from the seed. Even small amounts of fuzz impede its operation. Hence we have to consider possible means of supplying sowing-seed free from fuzz.

This can be done by the use of sulphuric acid (66% for five minutes), but with obvious inconveniences and actual danger to unskilled operators. Alternatively, a general adoption of dibble-sowing would make it worth while to remove the fuzz mechanically, at the ginnery of origin, from all seed which had been passed as fit for sowing under the Seed Control Law.

This can be done by the use of the De Segundo De-fibrator machine. From information very kindly supplied to us by the British Oil and Cake Mills, Ltd., we conclude that one such machine would cost about L.E. 100, and would handle at least 200 tons of seed during a four-month working season. Making allowance for the over-heads due to its standing idle for eight months of the year, the cost of such treatment would not exceed three piastres an ardeb, or less than half a piastre per feddan. There would however be some invisible costs on account of the supervision required to ensure that no mixing took place between successive lots of certified seed during treatment. We shall see later that we can afford this small expenditure even with the present procedure, and a magazine dibble would actually economise about seven piastres per feddan on labour.

3. Botanical Section Experiments.

Discovery and Analysis of the Effect on Yield.

The use of the dibble by the Botanical Section quickly became routine for cotton breeding. Also it was adopted for all chequer plot sowings, in order to minimise corrections for uneven stand of seedlings and for resowing. In 1929 the State Domains agreed to employ it in order to propagate the original stock of Giza 7 as fast as possible, and 400 feddans instead of 100 were thus obtained.

But it had not occurred to any of us that it could improve the actual yield, apart from the reduction of re-sowing. In 1931 a chequer was being laid out to demonstrate the value of earlier watering(1) under present-day conditions, and it was decided to duplicate the plots with dibble-sowing against ordinary sowing, merely to satisfy curiosity. The result was quite incredible, namely, in kantars per feddan of final yield :—

	Dibble Sowing	Ordinary Sowing	Advantage
Early sown, early watered	8.31	7.26	1.05
Early sown, late watered	8.05	6.70	1.35
Late sown, early watered	6.42	5.02	1.40
Late sown, late watered	5.89	4.12	1.77

These values will be found plotted on Fig. 1 as four encircled dots, and it will be seen, in the light of our later knowledge from the five hundred comparisons made in that graph, that there was nothing exceptional about them. Moreover, data for yield-analysis in the form of flowering-curves

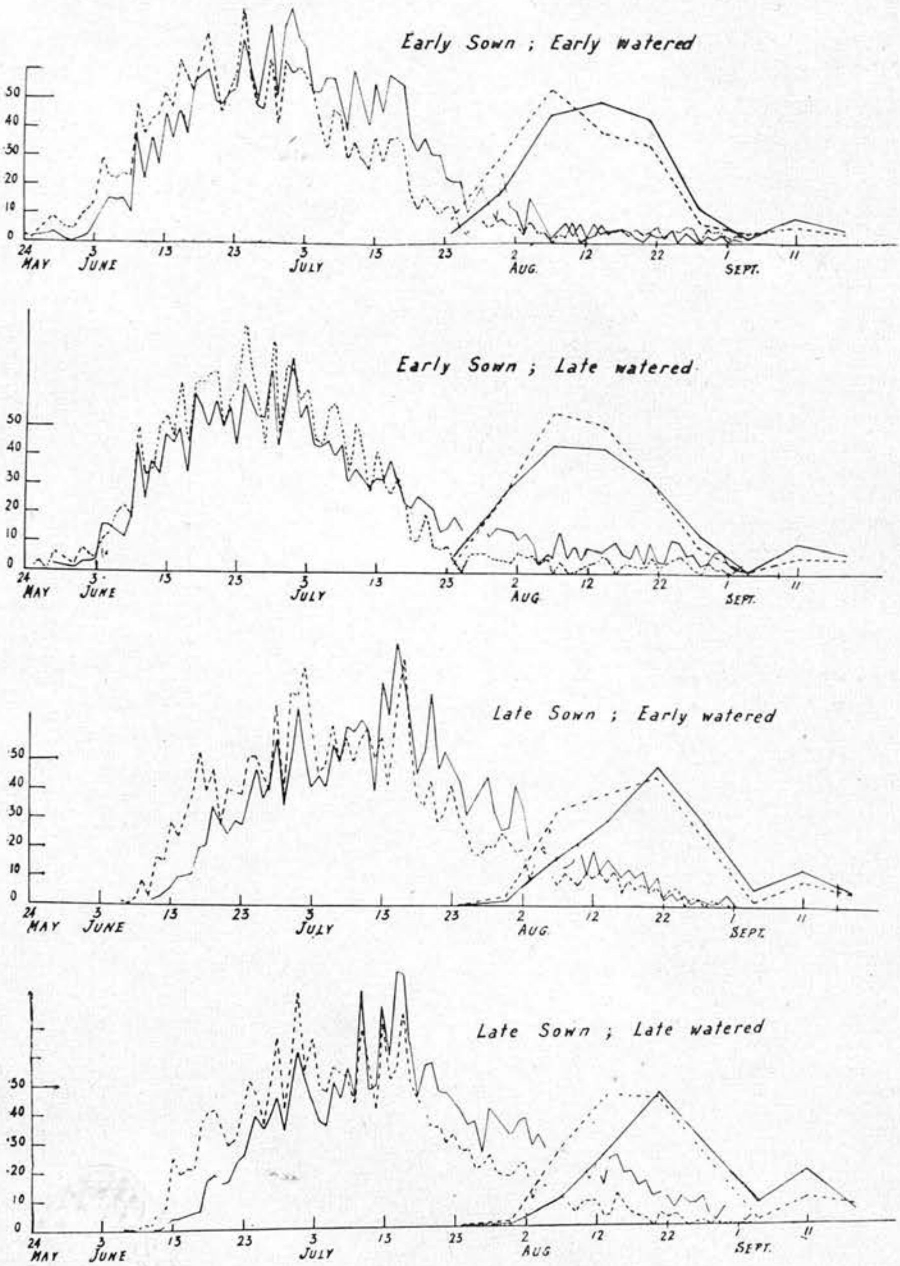
(1) W. L. B. " Analyses of Agric. Yield." Phil. Trans. Roy. Soc. **B, 352,** 188 (1916).

Fig. 7.

DISCOVERY OF EFFECT ON YIELD IN 1931

ORDINARY SOWING ______ DIBBLED -------

FLOWERING AND BOLLING CURVES, PER PLANT PER DAY



and bolling curves were available from the chequer in question, and these, which are presented in Fig. 7 show the building up of these remarkable yield-differences to have been quite simple and reasonable. The dibbled plants produced their first flowers at the same time as the best of the ordinary plants, but there were so many more of them in the "best condition" that the flowering curve for dibbling rose four to six days ahead of the ordinary curve, and rose rather higher. Later in the season the curves crossed over, as is usual in such cases, but this is immaterial because only the early flowers matter under modern Egyptian cotton-growing conditions.

The effects were less marked with early sown but late watered plants, and the advantage was almost confined to a higher maximum rate of flowering. Here we missed making a most important inference, which was not obtained until some years later by one of us (D.G.), namely :- that the well-grown, larger seedling obtained by the dibble is necessarily more likely to suffer from temporary water-strain on sudden hot days when there is no time for compensating root-development to take place. So it follows that the benefit from dibble-sowing is strikingly correlated with the timing of the water given (Fig. 14), and may even... with very inadequate water... be turned over into a small loss instead of a large gain.

The general form of the flowering curves was repeated in the bolling curves, which show the total yield as it develops week by week (Fig. 7). Thus there could be no doubt that, for 1931 season, using Giza 7 on Plot 11 of the Giza farm, there had been real yield-advantages of surprising dimensions from the employment of the dibble-sowing method which we have defined in the previous chapter. The differences were far too large to be accounted for by re-sowing differences, the amounts of this having been 17.5% and 8.2% for early and late ordinary sowing, as against 4.5% and 1.9% for early and late dibble-sowing. Even if the re-sown plants had no yield at all the difference could not be thus explained.

Seed-number Factor.

It was decided to devote two more seasons to re-testing the reality of this 1931 result, and simultaneously to attempt to analyse it. It seemed likely that much of the advantage might be due to having fewer roots in each hole, so that less damage was done to the roots of the two survivors in the act of thinning. Two tests of this could be made ; one by sowing only two seeds per hole, which needed no thinning at all ; the other by thinning with scissors instead of by pulling.

There was also a probability that the mutual shade given to one another by the seedlings in the ordinary clump of 10 - 15 seedlings might waste food material in building up long etiolated stalks. This could be tested by varying the number of seeds sown with the dibble, and comparing the same numbers with ordinary sowing. So a chequer was laid out on Plot 2 at Giza with duly replicated plots of the following arrangements:

A. Dibble-sown.		2 seeds.	Not thinned.
B.	Do.	4 - 5 seeds.	Thinned by pulling.
C.	Do.	Do.	Thinned by scissors.
D.	Do.	10 - 15 seeds.	Thinned by pulling.
E.	Do.	Do.	Thinned by scissors.
F. Ordinary sowing.		Do.	Thinned by pulling.
G.	Do.	Do.	Thinned by scissors.

The experiment was unfortunate in that Plot 2 lies on the north margin of the farm and happened to receive a temporary and accidental infiltration of sewage, causing such soil heterogeneity over the three feddans that the final yields were not significant. This did not apply so much to the selected observation groups of plants on which flowering and bolling was recorded, and the data from these are presented in Fig. 8. The records for the stand of seedlings from using only two seeds per hole have some casual interest, remembering that the Giza farm is in good tilth and that the sowing date was March 16th ; there were no seedlings in 3% of these two-seed holes ; in 17% there was only one seedling, and the remaining 80% had two. Otherwise stated, out of 200 seeds sown we obtained adult plants from 177 ; this $88^1/_2$% is not much less than the result of a germination test in an incubator.

Besides trouble from sewage infiltration, the plants suffered from bad weather and from a consequent attack of thrips. It was recorded that the two-plant holes were most affected by thrips, and then the five-plant holes. In spite of this our Fig. 8 shows marked distinctions in favour of small numbers of seeds, of thinning by scissors, and of dibble-sowing. One of the smaller areas of bolling curve is from the ordinary sowing and thinning, the largest from two undisturbed seeds. It is more clearly seen in the sensitive flowering curves how five seeds thinned by scissors is second best, but not much superior to the same number thinned by pulling. The use of 10-15 seeds is very decidedly inferior to that of 4-5, even with dibble sowing for both.

Thus far the result of 1931 was confirmed in principle, and shown to be largely due to the reduced seed-number which the use of the dibble makes possible. This is of great practical importance, because it has been frequently observed by us that growers and officials (and small boys also) who are new to dibble-sowing, cannot resist the temptation to pour into the hole the accustomed number of seeds, under the delusion that the chance of good germination is thereby improved.

Fig. 8.

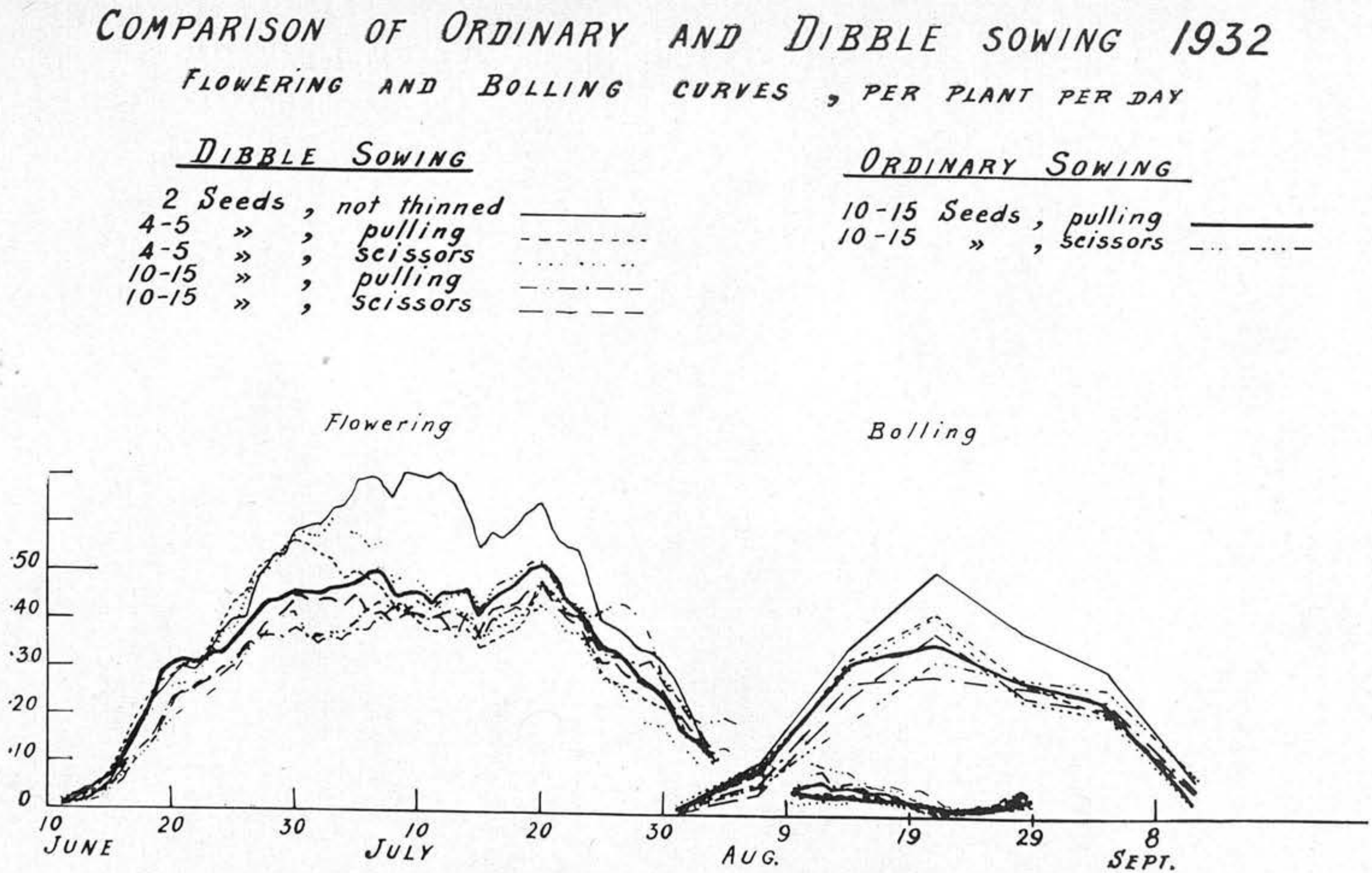
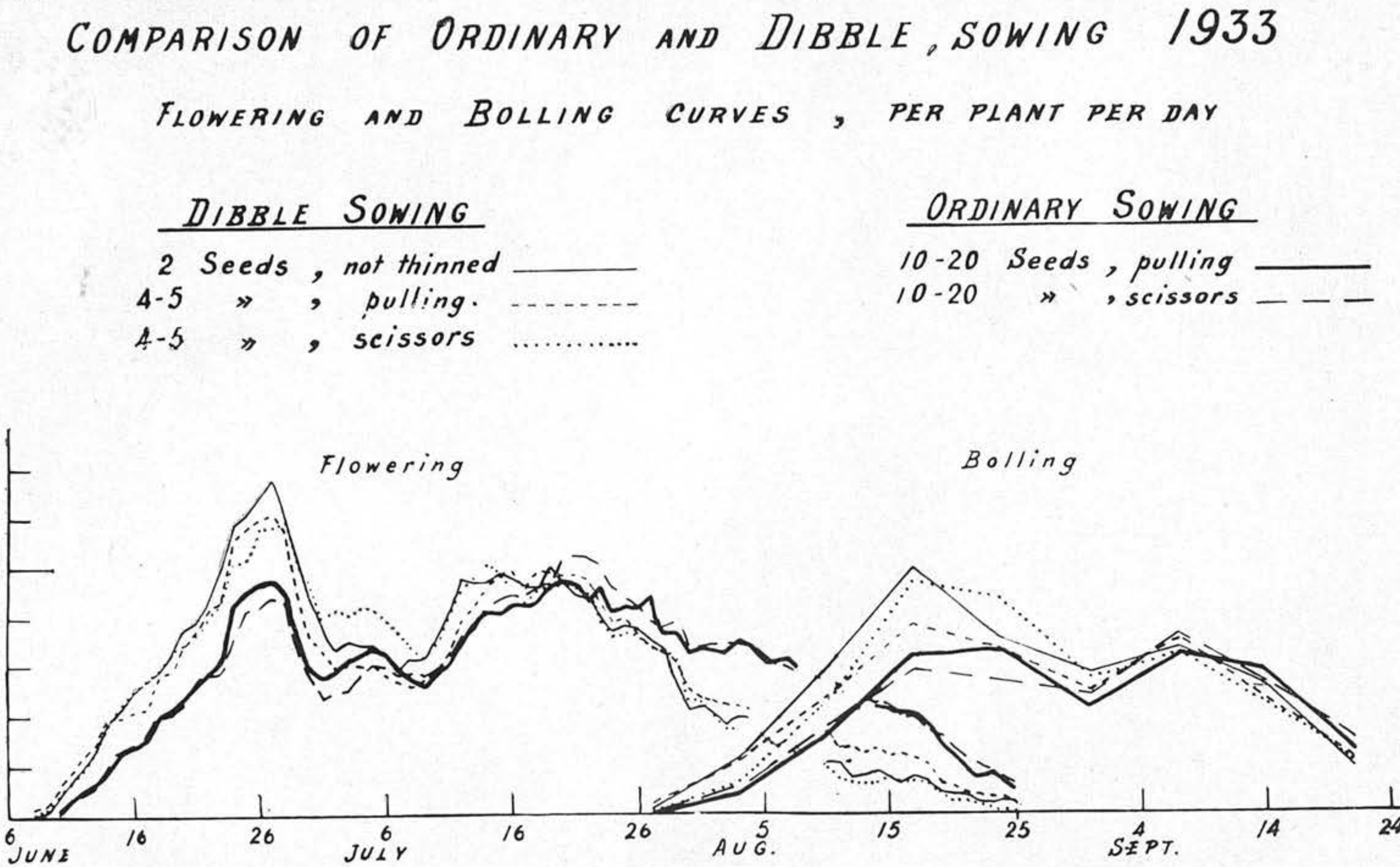

COMPARISON OF ORDINARY AND DIBBLE SOWING 1932
FLOWERING AND BOLLING CURVES, PER PLANT PER DAY
DIBBLE SOWING
2 Seeds, not thinned
4-5 », pulling
4-5 », scissors
10-15 », pulling
10-15 », scissors
ORDINARY SOWING
10-15 Seeds, pulling
10-15 », scissors
Flowering
Bolling
·50
·40
·30
·20
·10
0
10 JUNE
20
30
10 JULY
20
30
9 AUG.
19
29
8 SEPT.

Fig. 9.


COMPARISON OF ORDINARY AND DIBBLE, SOWING 1933
FLOWERING AND BOLLING CURVES, PER PLANT PER DAY
DIBBLE SOWING
2 Seeds, not thinned
4-5 " , pulling.
4-5 " , scissors
ORDINARY SOWING
10-20 Seeds, pulling
10-20 " , scissors
Flowering
Bolling
·50
·40
·30
·20
·10
0
6 JUNE
16
26
6 JULY
16
26
5 AUG.
15
25
4 SEPT.
14
24

Thinning Factor.

In 1933 the work was repeated on Plot 7 at Giza, and slightly simplified by omitting the useless dibbling of 10-15 seeds. It was noted that the dibble-sowings germinated a day sooner than the ordinary sowings, and that they were taller and had more flowering branches developed in May. The final yields are given in the following table : —

Treatment.			Kantars per Feddan.			
Sowing	Seeds	Thinning	1st. Pick	2nd Pick	Total Yield	Advantage
Dibble	2	—	4.15	3.57	7.72	1.05
Dibble	4 - 5	Pulling	4.36	3.82	8.18	1.51
Dibble	4 - 5	Scissors	4.40	3.88	8.28	1.61
Ordinary	10 - 20	Pulling	2.78	3.89	6.67	0.00
Ordinary	10 - 20	Scissors	3.08	4.14	7.22	0.55

The column headed "advantage" is based on the total yields in comparison with the ordinary method of sowing. As before, we observe a slight gain from not damaging the roots by pulling, and an outstanding advantage from dibbling only five seeds. The lessened advantage from dibbling two seeds instead of five would seem to disagree with the 1932 result, and also with the analysed presentation of the current result which is given in Fig. 9, but this is not so ; the flowering and bolling curves are based on "observation rows" containing the required number of perfect holes, each with two plants and none re-sown ; the total yields include single-plant holes and re-sowings, so that the advantage of two-seed sowing under ideal conditions is converted into a small disadvantage in practice.

The flowering curves are of particular interest in that their early portion shows a sharp separation between dibbling as such and ordinary sowing, and this separation is repeated in the opposite direction after the cross-over of the curves in mid-July, just as in Fig. 7. This late superiority of ordinary sowing is, of course, quite useless ; it does not appear in the bolling curve at all. It does however indicate that the dibbled plants have spent their lives under very different developmental conditions from those of the ordinary sowings. Some very interesting inferences can be drawn from study of these curves, but to do so would be beyond the scope of this bulletin. For the present we are only concerned to use them as a means of showing that the improvement in yield produced by dibble-sowing is real, reasonable, and understandable.

Pre-watering Factor.

We pass now to the work of 1934, in which year the Agronomic Section first incorporated dibble-sowing comparisons in the routine field experiments, which we have depicted in Fig. 1.

The use of a preliminary watering in dibble-sowing had been established as good practice, mainly because it is rarely possible to make a well-shaped hole (Fig. 3) with the dibble unless the soil is moist, nor does the pressure of the dibble produce its best results in re-distributing the soil water content. Amongst the criticisms engendered by these remarkable results from the three preceding years was one which ascribed the whole effect to the preliminary watering. That this was not correct can be seen by comparing the results for large and small numbers of seed, both dibble-sown, but direct experiment was desirable.

In 1934 the number of preliminary waterings was varied. At weekly intervals three, two, and one were given before sowing. The treatment was duplicated on plots sown at inter-plant intervals of 25 cm. and 35 cm., with the following result in kantars per feddan.

SPACING BETWEEN HOLES.	NUMBER OF PRELIMINARY WATERINGS.		
	Three	Two	One
35 cm.	6.85	6.75	6.55
25 cm.	7.60	7.38	7.27

Evidently a well-watered soil is rather better than a lightly watered one, and, by inference, still better than a dry one.

This experiment was much elaborated in 1938. Ordinary sowing was directly compared with similar sowing which had been pre-watered. This in its turn was compared with normal dibble-sowing. The comparisons were made on total yield, together with an analysis effected by measuring and weighing sample seedlings.

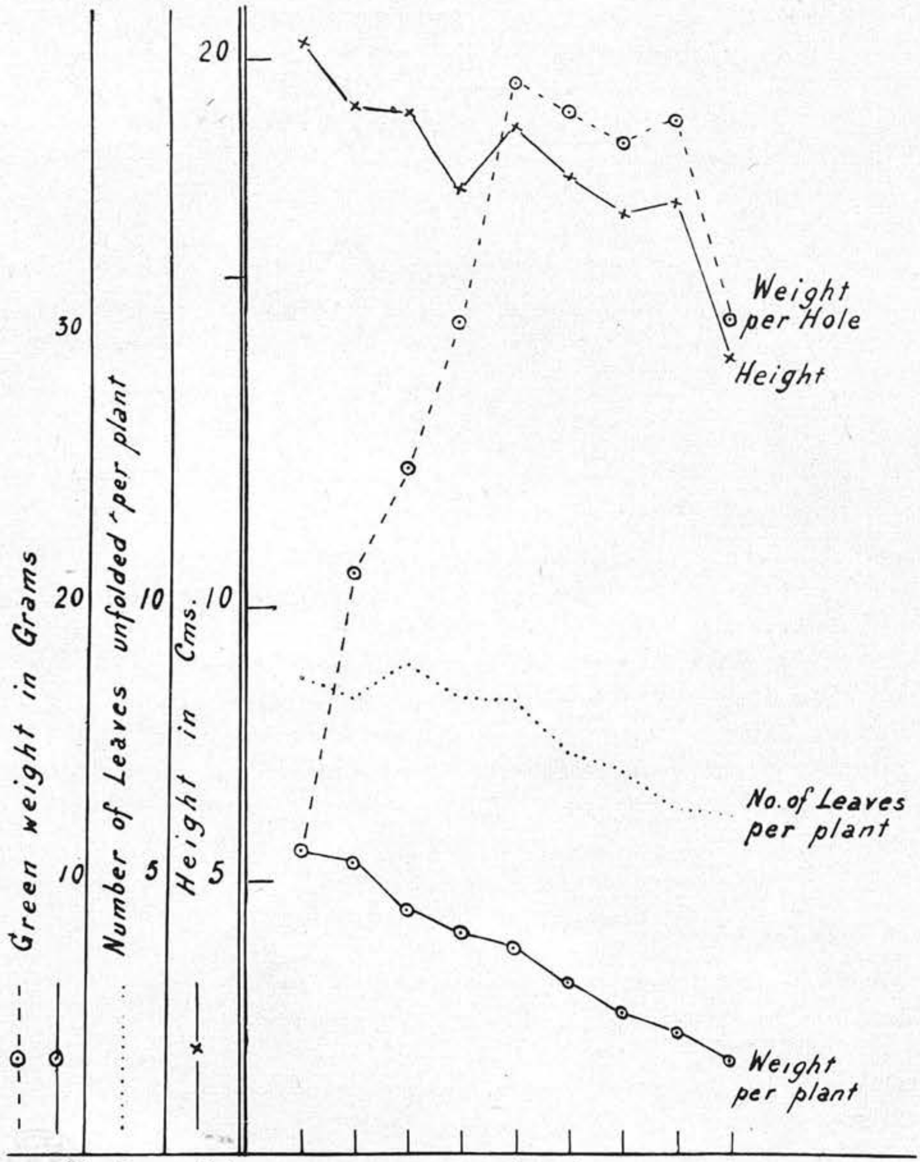
The first three treatments gave the following results at Giza, showing the dibble-sown plants to be vastly superior to ordinary ones: —

METHOD	DRY WEIGHT after 48 days	DRY WEIGHT after 70 days	HEIGHT after 70 days	KANTARS PER FEDDAN
Ordinary sowing with 20 seeds, not pre-watered	0.24 gm.	3.40 gm.	14 cm.	6.93
Ordinary sowing with 20 seeds *but* pre-watered	0.21 ,,	3.60 ,,	14 ,,	6.94
Dibble-sowing as usual with 5 seeds	0.43 ,,	4.80 ,,	17 ,,	7.64

Fig. 10

SEEDLING DEVELOPMENT IN RELATION TO NUMBER OF SEEDLINGS PER HOLE

AGE - SIX WEEKS



The kantars per feddan, unanalysed, were also measured at three other localities, as follows :—

Method	Sakha	Gimmeiza	(Giza)	Mallawi
Ordinary sowing with 20 seeds, not pre-watered	4.17	4.79	6.93	Not done
Ordinary sowing with 20 seeds, *but* pre-watered	4.70	5.48	6.94	6.81
Dibble sowing as usual with 5 seeds	5.10	6.51	7.64	7.26

It is evident that in certain soils and places the effect of pre-watering, though still only a part of the total dibble effect, may be quite appreciable. At Giza it was non-existent, at Gimmeiza relatively small, and it should be noted that Sakha and Mallawi are two typical localities where dibble-sowing has least effect ; between them they account for half the dots on the upper side of the equality line in Fig. 1. The reasons for this will be explained later. Meanwhile, bearing Fig. 1 in mind, we may safely conclude that while pre-watering is an essential part of dibble-sowing, its effect is unlikely to amount to more than one-third of the total benefit, on the average.

Seedling Competition Factor.

The final contribution at present to this physiological analysis of dibble-sowing is in relation to thinning. The injurious effect of pulling out redundant seedlings has been demonstrated ; with proper dibble-sowing there cannot be more than five seedlings per hole, and frequently fewer. If there are only three survivors, is it better to thin them to two slightly damaged, or to leave all three to suffer over-crowding ? Trials in 1934 showed that three plants per hole gave 7.94 kantars, as against 7.75 for two plants per hole, an advantage of only 2% but still not a loss. Linking this with a 1926 experiment, and also with 1912 data, we find that the relative yields from one, two, and three plants per hole stand in the ratio of 90.2, 100.0, and 102.4. It would seem to be safer practice to leave a three-seedling hole undisturbed.

The happier life of seedlings produced when only a few seeds are sown together is well exemplified by Fig. 10, which shows the results after six weeks growth when the number of plants per hole was varied from one to nine.

4. Agronomic Section Experiments.

The comparisons between dibbling and ordinary sowing (Fig. 1) which the Agronomic Section started to make in 1934 are quite different in character and scope from the investigations described above. They were done in all parts of Egypt, during five seasons, from the hot southern provinces to the Mediterranean climate of the northern Delta ; the soil fertility and conditions of growth ranged from crops of less than one kantar to crops exceeding thirteen kantars ; many of the comparisons were made on government farms, but many were also conducted on private estates ; apart from the use of the dibble in the appropriate sets of plots in each comparison there was no "experimental" treatment, the cultural operations and irrigation turns being simply those of normal practice on the farm employed or in the district concerned. The only result is the final yield, usually recorded in the form of two pickings.

The deliberate planning of the comparisons falls into four series in which different sowing dates, different varieties, different seed-rates, and (in 1938) different manurial treatment, were used for both methods of sowing. In addition to these deliberate differences we have been able to classify the effects of other differences due to the "practice of the farm", and sort out the mass of data now available in terms of locality effect, watering intervals, and so forth.

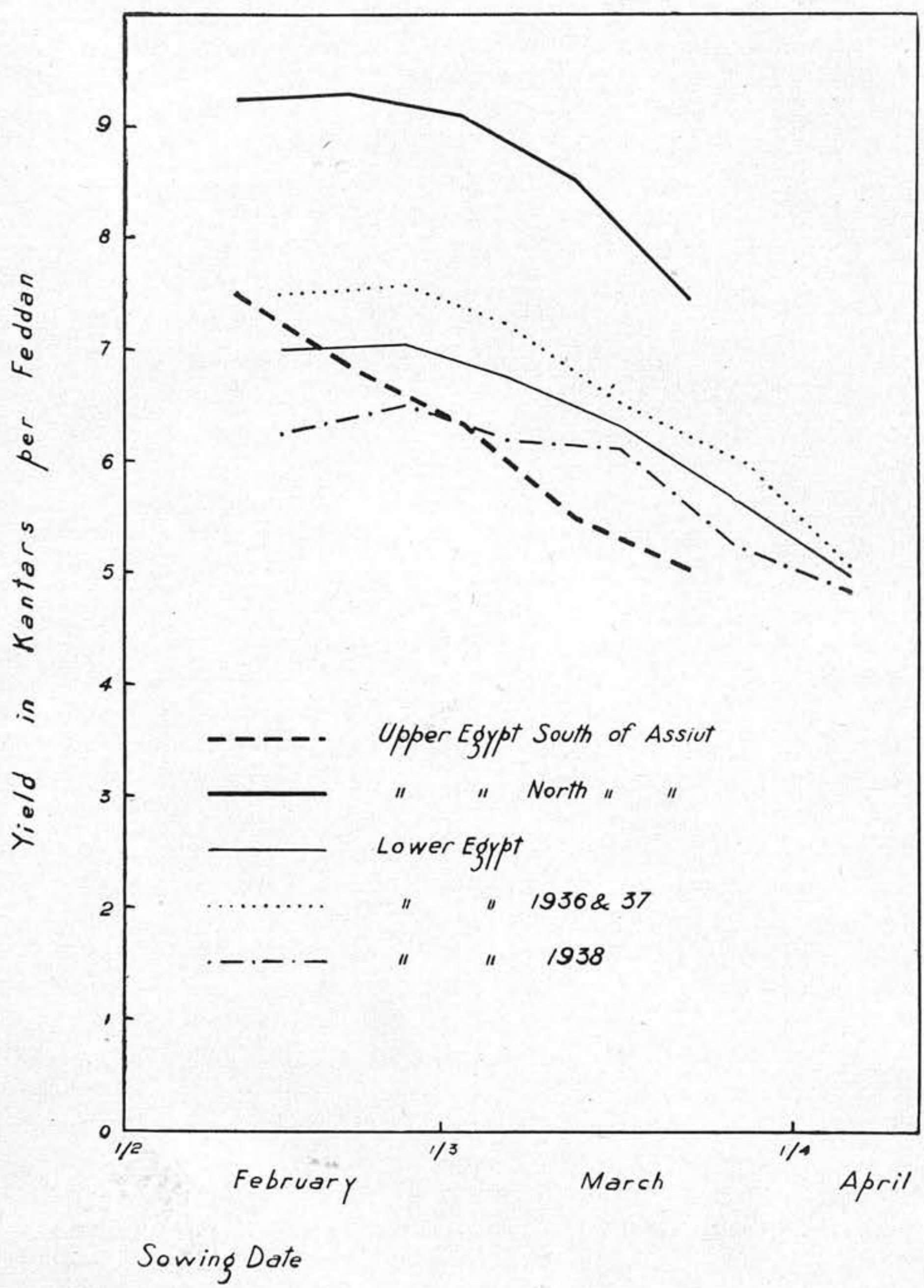
This dissection of the data has enabled us to give a very precise definition to the value of dibble-sowing, and to the conditions necessary for optimum advantage. So complete is this definition that we are even able to provide (and to explain) certain cases where the use of the dibble has actually reduced the yield, as the result of after-cultivation methods which were inadequate for the needs of the improved plants thus produced.

In the Appendix will be found the yield figures for the individual experiments of each series, except for manurial treatment, which will be published separately. The average effects will now be discussed, with citation of individual experiments as required.

Series with varying Number of Seeds.

There are thirty-two experiments in this series, covering 1934-7 inclusive, conducted at seventeen localities in both Upper and Lower Egypt. Ordinary sowing was compared with four kinds of dibbling, on chequers of twenty-five plots in Latin square arrangement, each plot being 1/40th of a feddan.

Fig. 11 GENERAL RELATIONSHIP BETWEEN YIELD AND SOWING DATE



TOTAL YIELD IN KANTARS PER FEDDAN

Sowing Date	All Lower Egypt 27 expts.,			All Upper Egypt 14 expts.,		
	Dibble	Ordinary	Advantage	Dibble	Ordinary	Advantage
Earliest ..	(7.02)	(6.77)	(0.25)	(10.53)	(9.74)	(0.79)
Second ..	7.11	6.81	0.30	8.96	8.10	0.86
Third ..	6.86	6.51	0.35	8.57	7.94	0.63
Fourth ..	6.52	6.14	0.38	8.41	7.47	0.94
Fifth ..	5.88	5.45	0.43	7.46	6.99	0.74
Last.. ..	5.22	4.71	0.51	6.47	6.38	0.09

PERCENTAGE OF TOTAL YIELD IN FIRST PICKING.

Earliest ..	(76.3)	(74.3)	(2.0)	(84.7)	(83.8)	(0.9)
Second ..	75.1	73.6	1.5	84.2	83.5	0.7
Third ..	71.8	68.4	2.4	83.3	82.2	1.1
Fourth ..	69.8	68.2	1.6	81.2	79.3	1.9
Fifth ..	64.8	61.8	3.0	75.1	73.6	1.5
Last.. ..	57.7	53.2	3.5	67.2	66.4	0.8

The first outstanding feature is not so much that the use of the dibble has given an advantage in total yield (and an increased proportion of the more valuable first picking), whatever date of sowing was used, but the rather unexpected result that the optimum sowing date is in no way affected by dibbling (Fig. 12). On the other hand the optimum advantage from dibbling is markedly affected by the sowing date ; it appears to be greatest with late sowing in the Delta, but with early sowing in Upper Egypt, this may be fictitious, since it scarcely seems reasonable, and may be in part explained by unsuitable use of the method at certain Delta localities, where the early dibble-sowings actually gave lower yields than ordinary sowings, and by the insufficient number of different localities in Upper Egypt.

Fig. 12 DIBBLE SOWING AND DATE OF SOWING

Yields

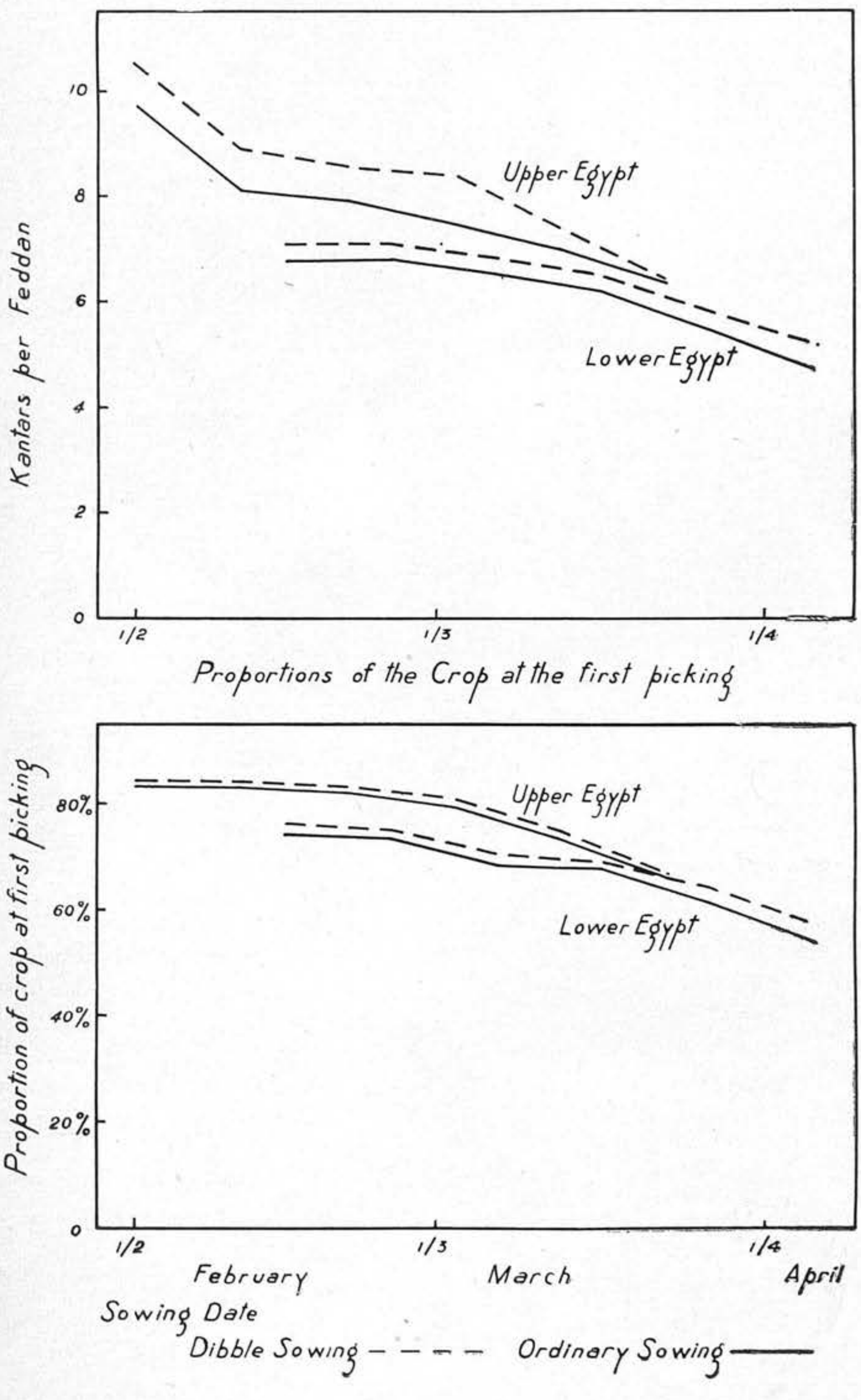
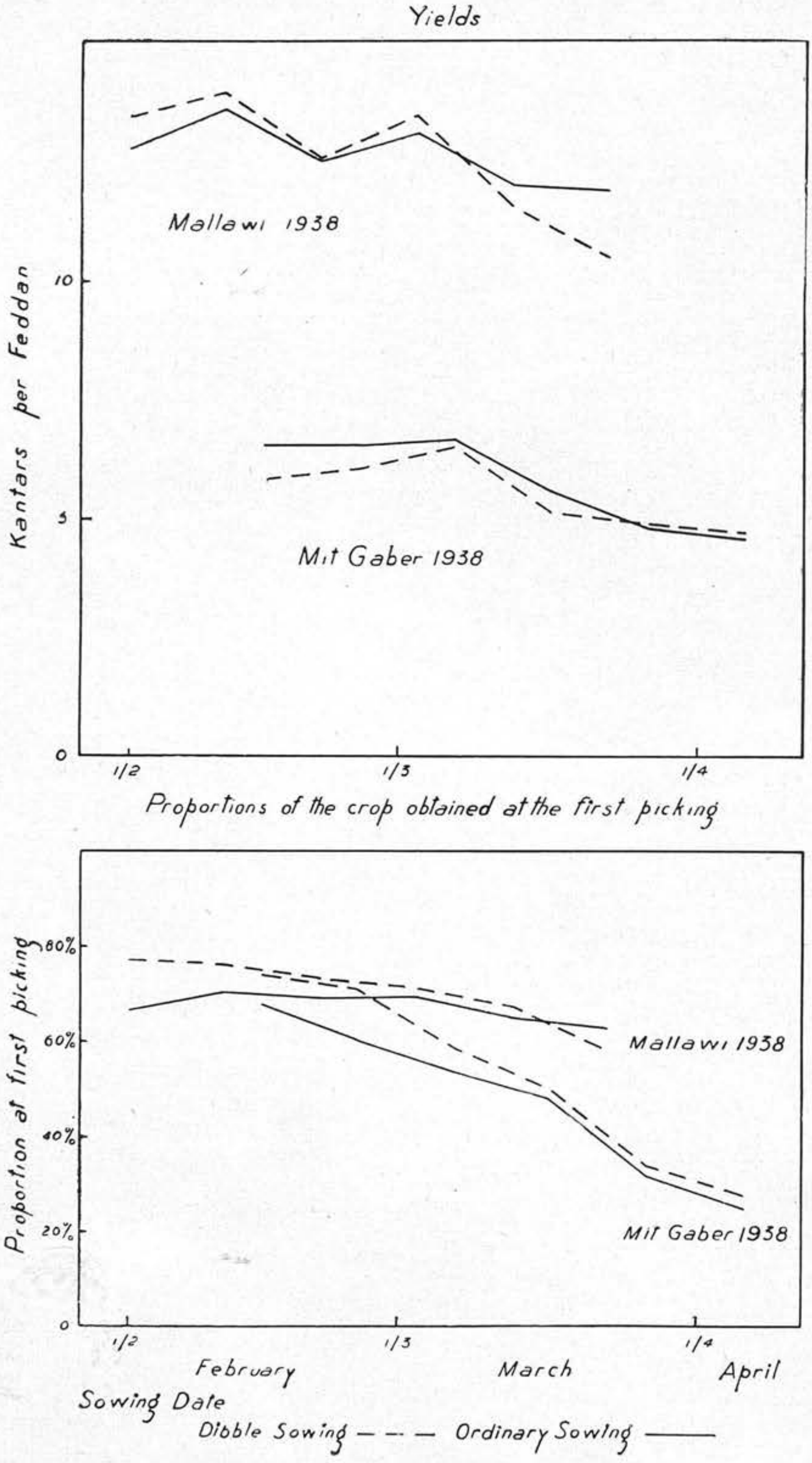


Fig. 13 DIBBLE SOWING AND DATE OF SOWING



A good example of a non-typical Delta result was at Mit Gaber in 1937, growing Giza 7, after beans, and picking on August 20th and September 27th, with the following yields (*see also* Fig. 13) : —

SOWING DATE	YIELD IN K. p. F.				PERCENTAGE AT FIRST PICK			
	Dibbled	Ordinary	Mean		Dibbled	Ordinary	Mean	
Earliest..	5.93	6.55	6.24		74.7	67.9	71.3	
Second ..	6.08	6.57	6.33		71.7	60.3	66.0	
Third ..	5.56	6.52	6.09	S.E.=	59.1	52.7	55.9	S.E.=
Fourth ..	5.14	5.56	5.35	0.10**	50.3	48.8	49.5	1.48**
Fifth ..	4.94	4.89	4.92		34.0	31.7	32.8	
Last.. ..	4.72	4.64	4.68		28.2	24.8	26.5	
Mean ..	5.40	5.81	5.60		53.0	47.7	50.3	
	S.E.=0.15**				S.E.=2.10**			

The effects of sowing-date and method of sowing were statistically very significant ($P = 0.01$) on yield and also on picking-ratio. Interaction between date and method was equally significant in affecting yield, but not in its effect on picking-ratio. Hence we infer that some environmental factor was unfavourable for dibbling in the early sowings ; it disappeared later. Since the picking-ratio is significantly in favour of dibbling, especially in the earliest sowings, we conclude that in this experiment the treatment of the young plants did not fully exploit the possibilities.

The locality-representation of Upper Egypt (latitude 25° - 30°) is confined to Mataana at latitude 50° and Mallawi near latitude 28°, during the last three years of the five, leaving the northern part of Upper Egypt unrepresented. Neither of these localities is typical, the former having exhausted soil very responsive to manuring, the latter being exceptionally fertile. The latter shows relatively small response to dibbling, or even a negative response ; the former responds enormously (*see* Fig. 1). Thus our averages represent an insufficient variety of conditions.

The corresponding non-typical result for Upper Egypt can be drawn from Mallawi in 1938, growing Giza 19 (Ashmouni) on soil which had been left fallow after wheat, and picking on August 30th and September 10th. (*see* Fig. 13) :-

Sowing date	Yield in K. p. F.				Percentage at first pick			
	Dibbled	Ordinary	Mean		Dibbled	Ordinary	Mean	
Earliest ..	13.42	12.78	13.10		77.6	67.6	72.6	
Second ..	13.93	13.63	13.78		76.1	70.5	73.3	
Third ..	12.57	12.53	12.55	S.E.=	73.8	68.9	71.3	S.E.=
Fourth ..	13.46	13.04	13.25	0.25**	71.7	69.6	70.6	1.14**
Fifth ..	11.55	12.02	11.79		66.7	65.4	66.2	
Sixth ..	10.50	11.89	11.20		58.2	63.0	60.6	
Mean	12.57	12.65	12.61		70.7	67.5	69.1	
	S.E.=0.61				S.E.=1.59**			

The method of sowing was not significant statistically in effect on yield, which was significantly affected only by sowing date. Method of sowing, date, and interaction between them were, however, highly significant in their effect on the picking-ratio, which is markedly improved by dibbling in the early sowings ; thenceforth the improvement fades away and turns over to an actual disadvantage in the last sowing. Similarly with the yields as such, for although they do not attain statistical significance, yet the benefit of 0.64 from dibbling early becomes a deficit of 1.39 on the last sowing date.

It will be shown next that absence of "water-strain" is an essential condition for success with dibble-sowing. Cases of small depressant effects are mostly random, but it would seem that in this experiment at Mallawi in 1938 the late sown dibbled plants started off too well to carry all the crop they could produce when the hot weather came, and so suffered a real disadvantage.

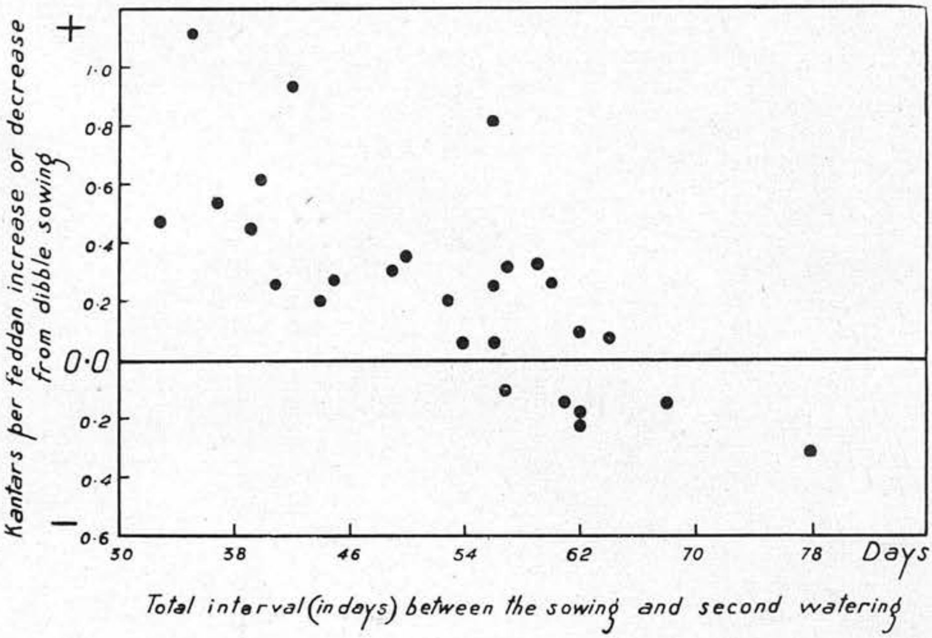
Extracted Data for the irrigation Requirements of Dibble-sowing.

In 1938 the usual Agronomic Section manurial experiments (thirty-one in number) were modified to compare dibbling with ordinary sowing under each manurial treatment. They are discussed as such below, but a side-issue of them was of such importance as to merit a separate chapter to emphasise it.

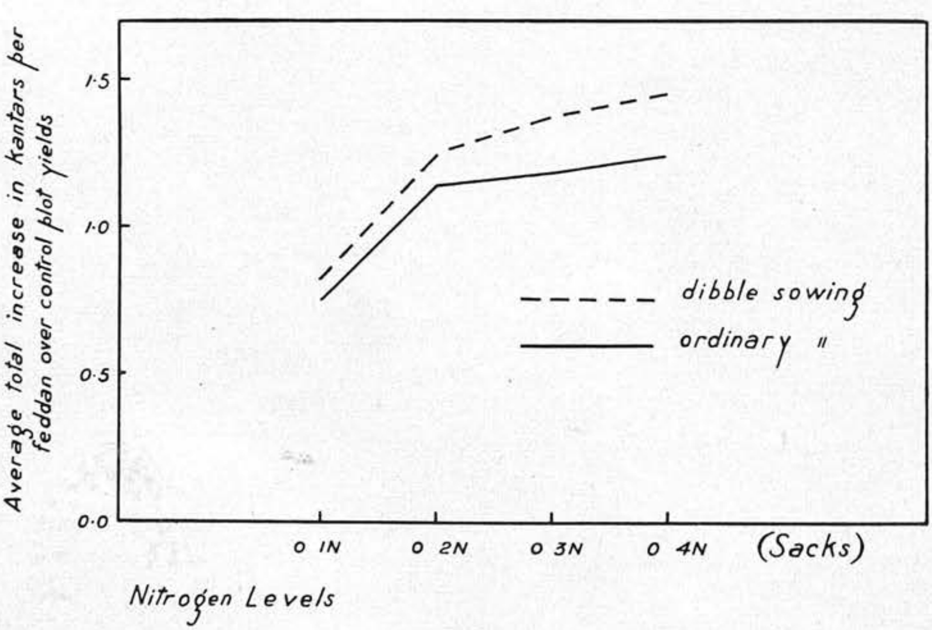
Statistical analysis of the results showed that in fifteen of the total of thirty-one experiments there were significant increases in yield from

Fig. 14 DIBBLE SOWING AND WATERING INTERVALS

(from manurial expts.)



DIBBLE SOWING AND INCREASE IN YIELD FROM NITROGEN



dibble-sowing; in three there were significant depressions; in the remaining thirteen there was no significant response either way. Interaction between nitrogen and method of sowing was significant only in seven experiments, five of them being in Upper Egypt. This seemed a very confusing set of results until the increase or decrease in yield from dibble-sowing (irrespective this time of significance) was set against both the interval (in days) between the sowing and first waterings and the total interval between the sowing and second waterings. The relationship in the first case works out at $r = -0.67$ and in the second at $r = -0.75$ (*see* Fig. 14) so that although the first interval is the more important the interval between the first and second waterings also has some influence. In calculating this relationship four experiments were dropped in which a "light watering" had been given in between the sowing and first waterings since it is not possible to define exactly what is meant by the term "light".

If dibble-sowing is practised it is therefore, and quite logically, of increased importance that the better plants resulting should not be subjected to water strain. No hard and fast rule can be laid down, since soils must obviously be treated according to their individual requirements (1) but it is essential to approach the question of water supply as much from the point of view of rate of renewal as from that of the total quantities given. The "practice of the farm" revealed in some of these experiments as leaving the cotton for a month or more without water after sowing has been demonstrated (Templeton) (2) years ago to be prejudicial, even with cotton sown in the ordinary way. It is of still greater importance with dibbled cotton and this more particularly so if the average season be taken into account. March temperatures in 1938 were the lowest for ten years so that the growth (*see* Fig. 11), whether of dibble or ordinary sown cotton, was much restricted, entailing a lessened demand on water

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(1) An interesting application of Fig. 14 can be made to the result obtained by Crowther, Tomforde and Mahmoud ("Further experiments on the Nitrogenous and Phosphatic manuring of Cotton", Bull. Roy. Agr. Soc. Egypt, No. 30, 1937.) who compared dibbling with ordinary sowing at Tukh and Shaba, the latter a "heavy salty" site. At Tukh they obtained 0.30 kantars advantage with a two-watering interval of 49 days, in good agreement with 0.35 which is indicated by the correlation axis of Fig. 14. At Shaba they had duplicated arrangements, which gave two-watering intervals of 46 and 62 days respectively and these should have given $+ 0.45$ and $- 0.05$, or an average advantage of only 0.20; actually they calculated a slight deficit of 0.07, but it is more than likely that in such salty soil the time-scale of irrigation intervals is even more important than in good soil. As theirs is the only published reference to dibble-sowing outside our Ministry, it is gratifying to find their result fitting so well within the framework of our knowledge.

(2) J. Templeton "Watering and Spacing Experiments with Egyptian Cotton" Technical Bulletin No. 112 of the Ministry of Agriculture, Egypt.

supply. In a season such as that of 1937 on the other hand where exceptionally high March temperatures rendered really early sowing in the Delta possible and exceptionally beneficial it is necessary to give added attention to watering practice. It is notable that in the Date of Sowing experiments discussed above the depression in yield from dibble-sowing at the earlier sowing dates is a more pronounced feature in 1937 than in any other year (e.g. the Mit Gaber experiment detailed above).

The average positive effect on yield over the whole thirty-one experiments was 0.24 of a kantar per feddan and for the fifteen experiments showing a significant positive difference 0.51 of a kantar. This latter figure is an obvious underestimate of what was possible, even in an adverse season such as that of 1938, since the watering practice was not necessarily at the optimum in all of these fifteen experiments.

Series with different Varieties.

A comparison of dibbling as against ordinary sowing was carried out in twenty-eight of the comparisons of cotton varieties during the years 1934-1938 (there are actually twenty-five to thirty of these experiments at different localities each year). The average benefit from dibble-sowing is greatest in this series of experiments. It amounts to 0.76 of a kantar per feddan in Lower Egypt alone and is still bigger in Upper Egypt. In only one experiment of the twenty-eight were there consistent depressions in yield from dibble-sowing. Correspondingly, the range in days of the interval between the sowing and first waterings was 17 - 33 as against 17 - 52 in the manurial experiments. It has already been suggested above that the average increase of 0.51 of a kantar per feddan obtained in the fifteen manurial experiments showing a significant positive response to dibble-sowing was probably an underestimate of what was possible, because even in their case watering was not necessarily at the optimum. The better watering practice in these variety experiments, the result of pure chance, confirms this suggestion ; thus the average benefit to be expected from dibble-sowing may be put provisionally at three-quarters of a kantar per feddan.

The varieties included in these comparisons are changed from year to year, so that only in the case of a few varieties is there an adequate number of observations for comparing the dibbling reactions of different varieties. The average figures from Lower Egypt for yield and for increases from dibble-sowing (in kantars per feddan), together with these increases as a percentage of the yield in ordinary sowing, and the weight of a hundred seeds in grams are as follows : —

Variety	Dibble sowing	Ordinary sowing	Increase from dibble-sowing	Increase as percentage of ord.	Weight [1] of 100 seeds in gm.	Number of observations
Giza 7	6.74	5.89	0.85	14.4	11.4	24
Giza 12	7.02	6.30	0.72	11.4	13.4	24
Giza 19	6.60	5.69	0.91	16.0	9.8	20
Giza 24	5.24	4.61	0.64	13.9	13.0	12
Giza 25	5.52	4.97	0.55	11.1	9.2	7
Giza 26	6.09	5.28	0.81	15.3	13.1	12
Giza 27	6.52	5.88	0.74	12.6	11.5	8
Giza 29	6.00	5.29	0.71	13.4	12.2	3
Giza 30	7.05	6.20	0.85	13.7	12.3	4
Sakha 4	4.86	4.11	0.75	18.2	11.3	17
Maarad	5.76	5.06	0.70	13.8		21
Fouadi	5.40	4.71	0.69	14.6	12.0	12
Bahtim Abiad	7.17	6.17	1.00	16.2	10.0	4

If the seed-weight figures in the above table are plotted against the average increases from dibble-sowing (whether expressed as percentage increase over ordinary sowing or as actual kantars per feddan) there is a very evident association. Small-seeded varieties tend to profit more from dibble-sowing as would be expected, smaller seedlings having more difficulty in breaking their way out, and so getting a worse start in life.

Series with various manurial Treatments.

The possibility that deficient nitrogen supply might be one of the factors occasioning the significant depressions in yield from dibble-sowing in Lower Egypt led us to alter the standard type of manurial experiment in 1938, so as to allow of a direct comparison between the effects of manure on dibbled and ordinary cotton. Five levels of nitrogen were employed (from 0 to 4 sacks of 100 kilos each), two levels of superphosphate and two methods of sowing, giving in all twenty treatments. The layout was in the form of six randomised blocks with plot size 1/40th feddan. Each experiment contained, therefore, one hundred and twenty plots and occupied three feddans. Results exist for thirty-one such experiments in 1938.

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(1) Seed weights provided by the Botanical Section from material grown at Gemmeiza except G. 19 (Fashn) G. 24, G. 26, and Bahtim Abiad (Sakha).

Effect of Nitrogen on dibble-sown Cotton.

The relevant average increases in yield when moving from one nitrogen level to another are set out below and illustrated in Fig. 14 : —

	AVERAGE INCREASES IN YIELD (kantars per feddan) IN MOVING FROM : —			
	0 - 1 N	0 - 2 N	0 - 3 N	0 - 4 N
	a. All experiments.			
Dibble-sowing	0.64	1.06	1.19	1.20
Ordinary sowing	0.69	1.00	1.10	1.12
	b. Fifteen experiments which showed significant positive differences in favour of dibble-sowing.			
Dibble-sowing	0.82	1.25	1.37	1.45
Ordinary sowing	0.74	1.15	1.19	1.24

Nitrogen is therefore entirely secondary in its effect. The better the conditions of growth, whether by suitable watering intervals, or by dibble-sowing or by the two together, the greater the effect of a given quantity of nitrogen. These data merely illustrate the general principle already established (Gracie, Khalil and Enan) (1) for nitrogenous manuring of cotton in Egypt ; *viz* : the higher the level of yield the greater the response to nitrogenous manures.

Owing to big weather differences the added nitrogen in our 1937 standard manurial experiments was about twice as efficient as it was in those for 1938. One would therefore expect in the average season, a larger advantage from nitrogen on dibble-sown cotton suitably watered than is shown by these comparisons made in the unfavourable season of 1938.

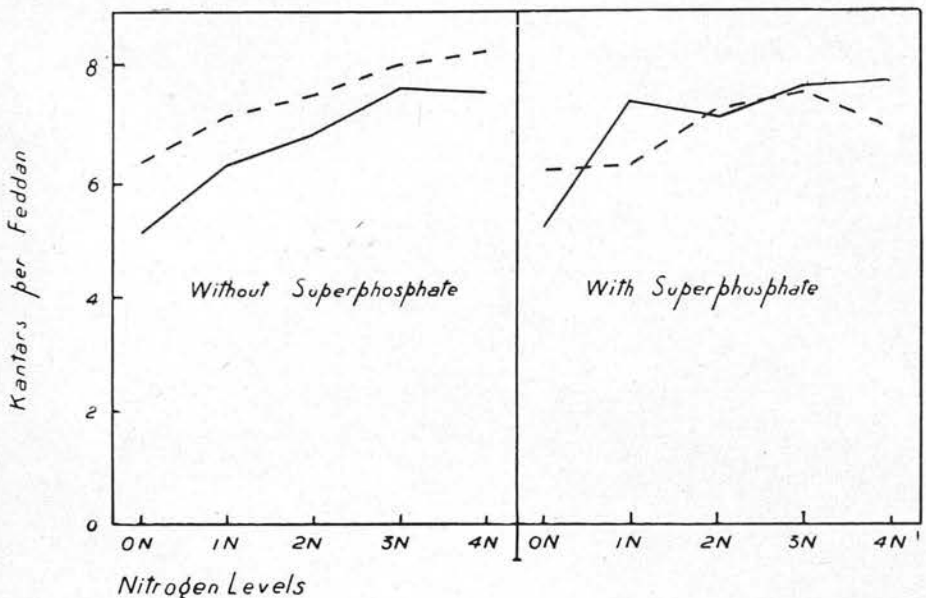
As stated when describing the effect of watering-intervals, interaction between dibble-sowing and nitrogen reached actual significance level ($P=0.05$) only in seven out of the thirty-one experiments, five of these being in Upper Egypt. The nature of the interaction varies. In two only of these seven experiments-one in Beheira and the other from Mataana (Qena province)-is the direct effect of dibble-sowing still significant

(1) Technical Bulletin No. 157 (1935) of the Ministry of Agriculture, Egypt.

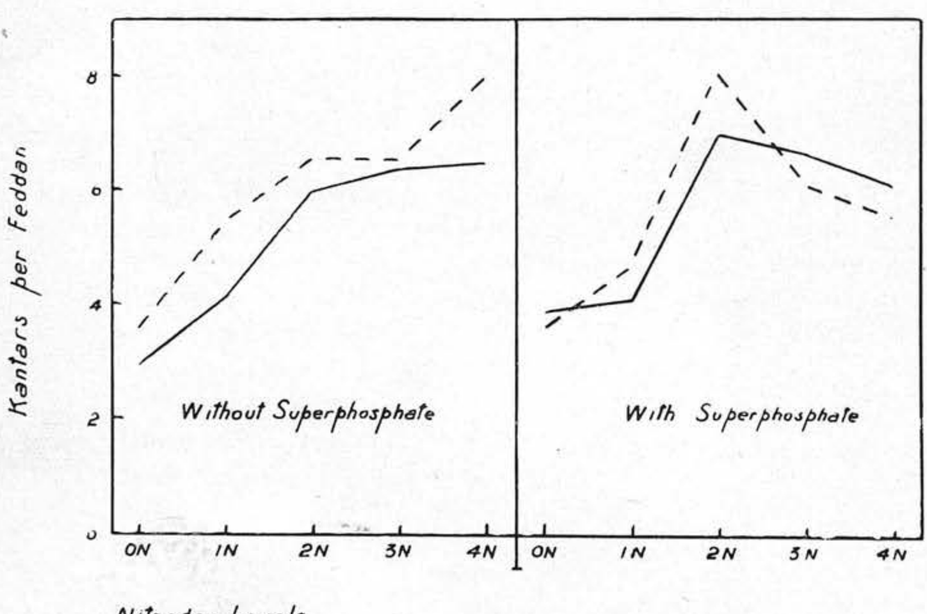
Fig 15

DIBBLE SOWING & SUPERPHOSPHATE

Kafr Hassan Saad (Qualiubia) 1938



Beni Ahmad (Beni Suef) 1938



Nitrogen Levels

Dibble sowing - - - - Ordinary sowing ———

when compared with the interaction as error, and in these two the interaction has the same effect as is brought out by the average figures given above, i.e. dibble-sown cotton utilized added nitrogen more efficiently. To these may be added the experiment at Minia where the direct effect from dibbling was insignificant (water-strain) but the interaction between nitrogen and method of sowing was significant, and had the same meaning.

Phosphate, Nitrogen and Method of Sowing.

The remaining four of the seven experiments which showed significant interaction between nitrogen and method of sowing merit the closest attention ; they are exceptional, in that the factor of available phosphate had a deciding influence on the result. The yield figures for the experiment carried out at Kafr Hassan Saad, Qualiubia, are as follows (*see also* Fig. 15):-

		0 N	1 N	2 N	3 N	4 N	Mean
0 P	Dibble-Sowing.	6.35	7.22	7.56	8.08	8.30	7.50
	Ordinary Sowing	5.18	6.34	6.86	7.64	7.60	6.72
2 P	Dibble-Sowing.	6.24	6.37	7.32	7.62	6.98	6.91
	Ordinary Sowing	5.25	7.45	7.15	7.68	7.81	7.07
	Means	5.76	6.85	7.22	7.76	7.67	7.05

S.E. = 0.21

The direct effect of superphosphate is not significant ; both nitrogen and method of sowing are directly significant, although, as noted above, the latter is not if the interaction be taken as error for comparison. The interaction between nitrogen and sowing-method and between phosphate and sowing-method are both highly significant. *The interaction between nitrogen and phosphate is not significant.* There is also a significant second order interaction between nitrogen, phosphate and method of sowing. Dibbling without superphosphate gives a consistent advantage in yield which *already tends to diminish with increased application of nitrate.* When superphosphate is given the advantage in favour of dibble-sowing is maintained only so long as no nitrate is added ; when nitrate is present the advantage is trivial or may actually be reversed. At Kafr Hassan Saad therefore the use of superphosphate on dibble-sown cotton manured with nitrate was definitely harmful.

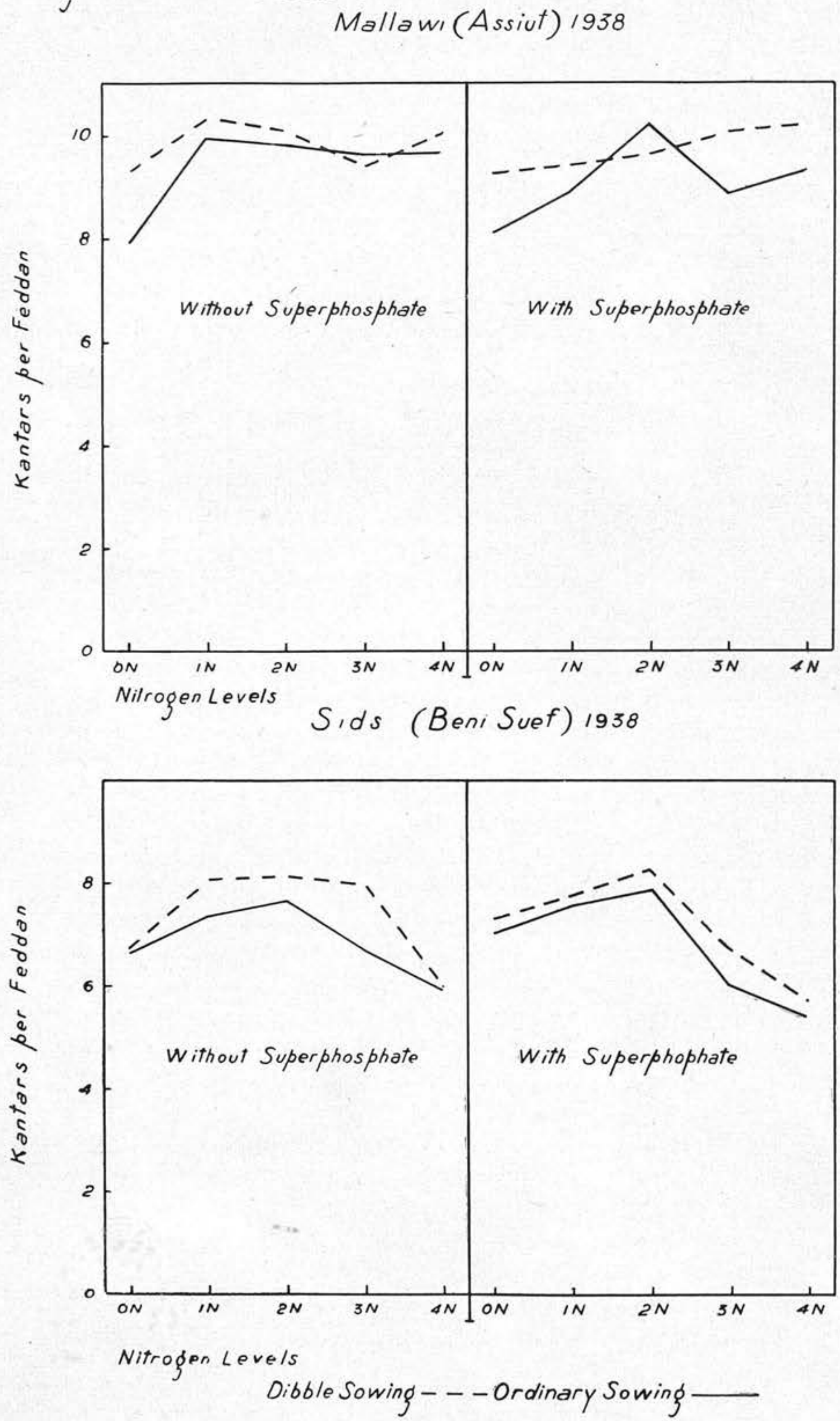
These interactions were all present, with the addition of a highly significant one between nitrogen and phosphate, in the experiment at Beni Ahmad, Biba (Beni-Suef province), the results of which are as follows (*see also* Fig. 15):—

		0 N	1 N	2 N	3 N	4 N	Mean
0 P	Dibble-sowing	3.60	3.48	6.56	6.50	7.98	6.02
	Ordinary sowing	2.94	4.13	6.01	6.39	6.48	5.19
2 P	Dibble-sowing	3.77	4.72	8.10	6.09	5.63	5.66
	Ordinary sowing	3.87	4.08	6.96	6.64	6.07	5.52
	Means	3.54	4.60	6.91	6.41	6.54	5.60
							S.E. = 0.28

The yield increases from fertiliser nitrogen in this experiment were very much greater than at Kafr Hassan Saad. In the series without superphosphate there is again a consistent advantage in favour of dibble-sowing with maximum yield (and benefit) at *four* sacks of nitrate. In the superphosphate series on the other hand owing to the interaction between nitrogen and phosphate a slightly higher maximum yield is obtained at the *second* sack in both methods of sowing, with dibble-sowing still maintaining its marked superiority. The addition of further nitrogen thereafter depressed the yield irrespective of sowing-method, and moreover the dibbled plots dropped significantly below the ordinary ones, an interaction between superphosphate and sowing-method.

The remaining two experiments which showed a significant interaction between nitrogen and method of sowing were conducted at Mallawi (Assiut province) and at Minshah (Girga province). In both there was a highly significant interaction between nitrogen and phosphate *(irrespective of method of sowing)* which meant that at Mallawi a small, and at Minshah a large, advantage from superphosphate given alone was converted into a disadvantage on the addition of nitrate as compared with the nitrate given alone. At Mallawi the interaction was so consistent that the direct depressant effect of superphosphate on yield became significant. In neither case was there significant interaction between superphosphate and sowing-method ; at Mallawi there was however a significant second-order interaction between nitrogen, phosphate and sowing-method. The results of the experiment at Minshah need not be considered further ; too long a period was allowed to elapse between the sowing and first watering

Fig. 16 DIBBLE SOWING & SUPERPHOSPHATE



(thirty-three days) so that in spite of a significant positive reaction to dibble-sowing the cotton must have experienced undue water-strain. The nature of the influence of superphosphate at Mallawi makes ambiguous our interpretation of the interaction there between nitrogen and method of sowing. The yield figures are given below (*see also* Fig. 16).

		0 N	1 N	2 N	3 N	4 N	Mean
0 P	Dibble-sowing	9.33	10.33	10.11	9.42	10.05	9.85
	Ordinary sowing	7.92	9.97	9.84	9.63	9.63	9.40
2 P	Dibble-sowing	9.29	9.46	9.56	10.05	10.28	9.73
	Ordinary sowing	8.17	8.89	10.22	8.82	9.29	9.08
	Mean	8.68	9.64	9.93	9.48	9.81	9.51
							S.E. = 0.21

A benefit exceeding a kantar per feddan is obtained from dibble-sowing on the plots not given nitrogen, which is much reduced when nitrate is added, although it still exists. Knowing of the markedly depressant effect of superphosphate, however, we may reasonably assume the soil to have been already so very well supplied with available phosphate that the ostensible interaction between nitrogen and sowing-method may be in reality an interaction between available soil phosphate and sowing-method, resembling the interaction between superphosphate and sowing-method experienced at Kafr Hassan Saad, as quoted above.

Interaction between nitrogen and superphosphate was also a feature of the experiment at Sids (Beni-Suef province), in which the direct effects of dibble-sowing and nitrogen were highly significant, but the only other significant feature was the interaction between nitrogen and superphosphate. The interaction was to a certain extent similar to that at Beni Ahmad (Biba), i.e. superphosphate increased the efficiency of added nitrate up to two sacks but this was the optimum, and the addition of further nitrate depressed the yield below that of the nitrate given alone. Both methods of sowing were affected equally so that dibble-sowing at Sids maintained an advantage at all levels of nitrogen. The figures for the Sids experiment are given below and illustrated in Fig. 16.

		0 N	1 N	2 N	3 N	4 N	Mean
0 P	Dibble-sowing	6.77	8.06	8.13	8.00	5.86	7.36
	Ordinary sowing	6.69	7.41	7.70	6.71	5.90	6.88

2 P	Dibble-sowing	7.37	7.83	8.32	6.75	5.74	7.20
	Ordinary sowing	7.07	7.62	7.87	5.99	5.42	6.79
	Mean	6.98	7.73	8.01	6.86	5.73	7.06
							S.E. = 0.36

These effects of superphosphate and nitrate on dibbled cotton are interesting and unexpected. We can use an analogy with the case of chlorosis in cereals (1) to provide a tentative explanation. Soils which are over-supplied with nitrate and phosphate in the warm climate of Upper Egypt provide conditions for growth which is so rapid that the cell-sap of the plant becomes too alkaline, consequent on too rapid reduction of nitrate. This causes precipitation of iron, in the form of phosphate. Iron deficiency reacts unfavourably on the formation of chlorophyll, and the carbon assimilation of the plant becomes a limiting factor in growth.

Summarising these manurial experiments :- it is clear that dibble-sowing has a direct effect on yield which is independent of the nitrogen supplied. It is not independent of superphosphate, for an excess of this in combination with the dibble and nitrate may have a depressant effect in the warmer parts of Egypt.

5. Statement of Account for Sowing Method.

By the courtesy of the Agronomic Section we have obtained detailed statements of farm accounts (Laboratory Research Committee Report, January 1939) for dibble-sowing and ordinary sowing on four farms, one in the Delta, and three in Upper Egypt. At the Delta farm the costs are compared for cotton sown after fallow, berseem, rice, and maize, and show that rice raises the cost of both methods by about ten piastres. On two Upper Egypt farms comparisons are available which show increased cost of 8 P.T. after maize as compared with dibbling after fallow or berseem.

We shall first examine the separate items, averaged for eleven different statements of account for each method in these four farms, per feddan.

(1) C. H. Wadleigh, W. R. Robbins, and J. R. Beckenbach. (1937). Chlorosis in corn. Soil Science, 43, 153.

Operation	Cost in Piastres Ordinary sowing	Cost in Piastres Dibble-sowing	Difference Against Dibbling	Difference For Dibbling
Pre-watering	—	5.0	5.0	
Purchase of sand and its transport	—	22.6	22.6	
Dibbling holes	—	11.2	11.2	
Covering with sand.. ..	—	15.3	15.3	
Purchase of seed and its transport	40.5	21.4		19.1
Sowing	6.7	9.9	3.2	
Watering after sowing ..	6.1	4.4(?)	—	—
Resowing, labour only ..	4.0	2.7		1.3
Thinning	7.8	5.1		2.7
Totals	65.1	97.6		

The practical importance of the seed costs can be better realised if we inspect the detailed figures again, and note that seed for ordinary sowing with about 15 seeds per hole at the rate of 5 kelas per feddan cost 40.5 P.T. whereas the seed for dibble-sowing with only 5 seeds per hole is priced at 21.4 P.T. We have previously mentioned that it is difficult to induce the persons concerned to keep to the low seed-rate needed for full advantage to be obtained when dibbling ; these accounts are documentary evidence of the fact. Actually, as practiced on the farm of the Botanical Section, the cost of the seed for dibbling should have been 14.0 P.T. Moreover, we have shown in previous pages, by several different types of demonstration, that it is not possible to obtain the full increase in yield unless this low seed-rate is employed.

Now that the financial economy of the low seed-rate has been demonstrated, as well as its yield-increasing power, it is to be hoped that growers will try to take advantage of it, even against their convictions, which convictions have been formed on the basis of ordinary sowing and are not applicable to dibble-sowing.

We are indebted to the Botanical Section for the following supplementary information about the costs on their farm at Giza:-

Wage of labourer, 5 P.T. : wage of boy, $2^1/_2$ P.T. : sand used per feddan o.75 cub.m. : seed-rate ordinary, 5 kelas per feddan : seed-rate dibbling, $1^1/_2$ to 2 kelas.

Operation	Ordinary sowing	Dibbling
Pre-watering (one man)	—	5.0
Purchase and transport of sand.. ..	—	12.0
Dibbling holes (four boys)	—	10.0
Covering with sand (three boys).. ..	—	7.5
Purchase and transport of seed	40.0	14.0
Sowing (three boys)	7.5	7.5
Watering after sowing	5.0	5.0
Re-sowing (labour only)	5.0	2.5
Thinning..	5.0	5.0
Totals	62.5	68.5

The costs by the two methods are much the same. Nevertheless these figures show clearly the extra labour demand for dibbling to be ten boys and a man instead of three boys, and they emphasise the need for labour economy by semi-automatic devices (Fig. 6).

A third set of figures from a farm in the middle Delta is substantially the same, but the seed-cost item is reduced by the use of seed not purchased direct from the Government. They are worth inclusion for that reason.

Operation	Ordinary sowing	Dibbling
Pre-watering	—	5.0
Purchase and transport of sand.. ..	—	23.0
Dibbling holes	—	6.0
Covering with sand	—	6.0
Purchase and transport of seed	28.0	14.0
Sowing	6.0	6.0
Watering after sowing	3.0	3.0
Re-sowing (labour only)	2.0	2.0
Thinning..	6.5	4.5
Totals	45.5	69.5

We might claim another piastre on re-sowing and a few more for a better seed-rate, leaving an extra cost against dibbling at 20.0 P.T. Compared with the scale of profits involved it may be concluded that dibbling and ordinary sowing cost much the same, when the value of the economised seed is duly taken into account, and when the supply of labour is sufficient to do all the sowing needed without raising the price of labour.

Invisible Costs.

Although the figures provided above are a complete statement of account for operations on these farms, those who have actually cultivated a cotton crop will rightly contend that they take no account of the invisible cost of additional supervision and planning on the part of the management. Pre-watering is a case in point ; we may pre-water five feddans on Saturday, planning to sow it on Thursday, but a khamseen wind on Monday may make it unfit for sowing later than Wednesday ; all the available labour is already engaged on Wednesday for its proper task, so we must either sow badly on Thursday or re-water at extra cost and delay sowing another week. Labour is another difficulty ; in many localities in Egypt there may be an actual labour shortage at sowing time if weather conditions have limited the sowing period, and as yet it must be conceded that dibble-sowing requires three boys instead of one, thereby enormously increasing the chance of labour shortage. Nevertheless this objection must not be given too much weight ; we have seen that labour-saving dibbles are feasible, and after our demonstration that dibble-sowing can cost little more than ordinary sowing, it becomes financially practicable to consider the technical and practical possibilities of removing the fuzz from the seed, so as to make semi-automatic manipulation easy.

Summary.

Dibble-sowing was devised to economise seed in 1913, brought to its present form in 1927, found to increase the yield in 1931, and exhaustively tested throughout Egypt during 1934 to 1938.

It consists in the use of a conical dibble making a hole one inch deep below a flattened surface in pre-watered soil. Only five seeds may be placed in the hole. They are covered with sand, silt, or dust, and given the usual sowing watering. Subsequent irrigations must avoid any risk of water-shortage.

The increase of yield is due to the greater number of adult plants which are in "best condition", consequently increasing the size of the first picking.

The average increase in ordinary good cultivation amounts to seventy rotls (pounds) of lint (Fig. 1).

Deprivation of water, and sometimes an excess of phosphate in combination with nitrate, reduces this increase, and may even convert it into a small deficit.

Good watering in soil of bad tilth has given increases exceeding three hundred rotls.

The optimum sowing date is not altered by using the dibble.

The average amount of re-sowing after dibbling is much less than that required ordinarily.

All varieties show the dibbling increase in yield, and small-seeded varieties benefit more than large-seeded varieties.

A complete accountancy of the cost of sowing with the dibble shows slight disadvantage in comparison with sowing in the ordinary way.

Thus the whole of the increase in yield is pure profit (gross) to the grower. This increased profit is further increased because all the extra cotton is first picking, with less boll-worm damage, higher grade, and consequently of increased value per kantar.

The financial and economic significance of dibble-sowing is thus enormous. The invisible costs of extra trouble in organization may be high, but the reward for them approaches a whole kantar of first-picking cotton. It affords a means of reducing the cost of cotton production in Egypt by about L.E. 2 per feddan.

Though we stated in our Introduction that the profit to Egypt annually could be L.E. 2,000,000, it should now be evident to the reader that this was a conservative and cautious under-statement.

Acknowledgements.

Many helpers have contributed to the accumulation, dissection, and presentation of the data in this Bulletin.

In developing the method, F. S. Holton (1913) Gedalla Abou El Ela (1928) Dr. Fahmy Khalil and Mahmoud Mufid.

The physiological comparison of plants and crops, by Dr. J. Templeton, and especially by Mohammad Zaghloul. The records of Zaghloul's field work have been computed, plotted, and filed by A. Weinstein.

The whole staff of the Agronomic Section have to be thanked for their five years accumulation of data. In the analysis of these we have had the assistance of Dr. Khalil, and of Mohammad Kamal Mohammad, Mohammad El-Kadi, Ahmad El-Shabasi, and Abd El-Ghani Mitkees of the Chemical Section.

The data for statements of account have been provided by Hussein Thabit and Armenag Bedevian.

The accurate draughtsmanship in preparing the diagrams is due to A. Weinstein, O. Gluckmann and A. Karadjian.

The photographs are made by Said Awad from specimens and demonstrations prepared mostly by Mohammad Zaghloul.

APPENDIX OF AGRONOMIC SECTION STATISTICAL DATA

DIBBLE-SOWING WITH A VARYING

Locality	Ordinary Sowing		Dibble-Sowing 5 seeds thinned to 2		Dibble-Sowing 3 seeds thinned to 2		Dibble-Sowing 3 seeds not thinned	
	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking
				1934.				
Gimmeiza	7.29	56.4	7.80	68.1	8.30	65.1	7.70	61.7
Defra	7.75		8.10		7.97		8.10	
Ez. Khorshid	5.29	77.4	5.56	79.5	5.51	82.9	5.88	84.8
Sids	3.48	51.1	3.99	51.6	4.12	54.9	3.76	54.7
Mallawi	8.64	96.2	8.68	97.4	8.35	95.7	8.25	95.8
Mataana	5.44	95.3	5.11	96.0	5.56	94.1	5.89	95.7
				1935.				
Gimmeiza	8.18	30.9	9.13	39.6	8.74	40.0	9.24	43.4
Defra	8.34	69.7	9.14	70.8	8.42	69.7	8.52	70.0
Itai-el-Baroud	7.24	42.8	7.19	45.6	6.91	37.9	6.81	39.2
Halawat	6.48	89.8	6.71	90.9	6.78	91.0	6.93	91.2
Mallawi	11.12	80.1	11.50	81.0	11.50	76.6	11.48	77.2
Mataana	8.74		8.66		8.25		8.12	
Kom Ombo	5.21		5.59		4.88		5.26	
				1936.				
Gimmeiza	5.96	63.5	5.75	69.8	5.50	63.0	5.80	65.0
Sakha	4.34	93.6	4.64	94.0	4.47	93.7	4.49	93.8
Defra	8.12	87.5	8.73	88.4	8.71	86.0	8.84	86.2
Itai-el-Baroud	4.32	65.9	4.47	69.9	3.94	63.2	4.14	60.1
Qaraqis	9.07	85.4	9.22	86.8	8.89	85.1	9.22	86.0
Halawat	5.08	91.0	5.48	86.6	5.46	89.3	5.25	88.9
Mallawi	11.15	85.9	10.64	86.6	11.20	84.1	10.36	86.8
Mataana	6.17	63.8	7.62	82.7	7.01	80.8	7.62	76.3

NUMBER OF SEEDS PER HOLE.

Dibble-Sowing 2 seeds not thinned		Sowing date	Picking dates	Previous crop	Variety
Kantars per feddan	o/o at 1st picking				
1934.					
8.05	62.5	7/3	28/8 & 10/9	Berseem c.c.	Giza 7
7.85		28/2	1/9 one picking	Berseem c.c.	Giza 12
5.13	77.2	14/3	2/9 & 23/9	Maize	Giza 7
4.24	62.3	27/2	22/8 & 8/10	Maize	Ashmouni
8.05	95.3	26/2	11/9 & 11/10	Maize	Giza 19
5.21	94.6	15/2	28/8 & 10/10		Giza 3
1935.					
9.01	41.7	5/3	8/9 & 29/10	Maize	Giza 7
8.25	67.4	4/3	12/9 & 4/10	Kidney Beans	Giza 12
6.27	38.5	4/3	20/9 & 11/10	Fal. after Berseem	Sakha 4
7.01	91.3	21/3	25/9 & 21/10	Fal. after Berseem	Ashmouni
10.54	71.1	19/2	3/9 & 13/10	Kidney Beans	Giza 19
8.05		4/3	25/9 one picking	Barley	Giza 3
5.12		17/2	28/8 & 5/10	Wheat	Giza 3
1936.					
5.08	58.2	14/3	28/8 & 26/9	Berseem c.c.	Giza 12
4.08	92.5	27/3	28/9 & 14/11	Rice	Sakha 4
8.16	85.7	25/2	26/8 & 20/9	Maize	Giza 12
3.96	53.8	18/3	1/9 & 5/10	Rice	Sakha 4
9.22	84.0	12/3	7/9 & 7/10	Berseem c.c.	Giza 7
4.26	86.3	19/3	8/9 & 28/9	Berseem	Giza 7
10.59	88.5	24/2	30/8 & 5/10	Maize	Giza 19
7.64	73.1	18/2	5/8 & 9/9	Maize	Giza 12

DIBBLE-SOWING WITH A VARYING

Locality	Ordinary Sowing		Dibble-Sowing 5 seeds thinned to 2		Dibble-Sowing 3 seeds thinned to 2		Dibble-Sowing 3 seeds not thinned	
	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking	Kantars per feddan	o/o at 1st picking
1937.								
Gimmeiza	8.16	37.0	9.54	46.4	9.51	48.3	9.10	45.7
Sakha	3.58	55.4	3.42	52.6	3.22	47.2	3.40	50.0
Siberbai	9.14	51.9	8.81	50.3	8.63	51.8	9.11	52.6
Kom Zamran	11.37	80.4	12.03	84.2	11.80	84.1	11.63	82.1
Mit Gaber	5.04	56.3	5.49	69.3	5.57	68.8	5.34	72.4
Kafr Hassan Saad.. ..	10.33	47.9	10.41	51.5	10.94	55.7	10.54	55.9
Sids	7.23	42.8	7.27	41.5	6.96	39.8	6.71	38.9
Maghagha	9.01	31.0	8.12	29.4	6.96	33.9	6.90	25.0
Hawaslia	11.30	72.6	11.48	69.7	10.74	65.0	10.54	64.5
Mallawi	11.02	90.1	11.53	92.1	11.04	91.7	11.50	92.3
Mataana	9.24	68.1	12.80	83.3	12.90	81.7	13.38	80.1

NUMBER OF SEEDS PER HOLE *(Cont'd.)*.

Dibble-Sowing 2 seeds not thinned		Sowing date	Picking date	Previous crop	Variety
Kantars per feddan	o/o at 1st picking				
			1937.		
9.31	44.6	16/3	28/8 & 29/9	Berseem c.c.	Giza 12
3.47	46.0	12/3	9/9 & 12/10	Berseem c.c.	Sakha 4
8.78	49.7	16/2	21/8 & 26/9	Maize	Giza 7
10.84	79.4	8/3	3/9 & 28/9	Fallow after Berseem	Giza 7
5.34	65.1	26/2	29/8 & 27/9	Beans	Giza 7
9.53	52.1	7/3	24/8 & 17/10	Maize	Ashmouni
6.31	39.8	14/2	5/8 & 14/9	Maize	Ashmouni
7.21	33.1	17/2	15/8 & 12/9	Maize	Ashmouni
10.61	65.6	26/2	17/8 & 23/9	Maize	Ashmouni
11.40	88.0	13/2	28/8 & 5/10	Fallow after wheat	Ashmouni
12.39	80.7	25/2	19/8 & 18/9	Fallow after sugar-cane	Giza 12

DIBBLE-SOWING AND DATE

1934.

LOWER

SOWING DATE	A 26/2		B 7/3		C 17/3		D 28/3	
Locality	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan,	o/o at 1st picking
Gimmeiza	7.42	63.0	7.70	64.7	6.96	54.0	6.20	37.3
	6.45	54.3	6.91	56.7	6.55	47.3	5.11	36.3
Difra	7.67	95.7	7.70	96.0	7.52	95.3	7.16	92.2
	7.49	96.3	7.47	96.3	7.72	95.4	6.68	91.6
Qaraqis	6.91	54.0	6.88	51.3	6.17	57.2	6.25	78.0
	6.58	55.4	6.40	49.2	5.98	61.7	6.10	79.6
Ez. Khorshid	5.21	69.7	5.64	72.1	5.23	86.9	3.99	85.3
	4.90	68.9	5.31	71.5	4.98	84.2	3.53	82.0

UPPER

	A 1/2		B 11/2		C 21/2		D 3/3	
Sids			3.96	74.4	4.04	78.0	4.87	77.8
			3.51	74.6	3.78	78.5	3.48	75.2
Hawaslia..	9.96	95.7	10.31	95.3	9.48	94.6	10.84	94.1
	8.74	95.9	9.27	95.3	8.87	95.1	8.74	94.5
Mallawi			9.15	93.9	9.55	94.7	9.88	94.3
			8.51	93.1	9.32	94.0	9.58	95.2
Mataana			8.28	95.4	8.13	95.9	7.65	95.0
			7.57	95.6	7.47	95.9	6.35	95.6
Kom Ombo			5.18	76.5	5.00	82.2	4.93	86.1
			4.35	94.2	4.12	95.1	3.94	95.5

OF SOWING EXPERIMENTS.

1934.

EGYPT.

E Kantars per feddan.	6/4 o/o at 1st picking.	Variety	Picking dates	Previous crop	Method of sowing
5.33	21.4	Giza 7	20/8 &	Berseem	Dibble
4.39	18.5		10/9	c.c.	Ordinary
5.82	86.0		9/9 &	Sesame	Dibble
5.44	84.1		?		Ordinary
6.50	73.0	Giza 7	At various dates separately	Rice	Dibble
5.99	74.6				Ordinary
3.15	85.5	Giza 7	At various dates separately	Maize	Dible
2.97	82.9				Grdinary

EGYPT.

E	13/3	F	23/3	Variety	Picking Dates	Previous Crop	Method of sowing
3.76	70.9	3.30	76.9	Ashmouni	26/8 &	Maize	Dibble
2.74	65.7	3.10	77.0		9/10		Ordinary
10.90	89.1	9.42	89.2	Ashmouni	30/8 &	Berseem	Dibble
9.40	90.6	8.79	89.6		9/10	c.c.	Ordinary
9.58	94.4	8.41	91.7	Ashmouni	6/9 &	Maize	Dibble
9.45	93.0	8.53	91.7		8/10		Ordinary
6.40	96.0	5.46	91.6	Giza 3	27/8 &		Dibble
6.40	95.2	5.46	93.0		10/10		Ordinary
4.12	88.3	4.75	90.9	Giza 3	2/9 &	Millet	Dibble
4.47	95.4	4.22	95.2		8/10		Ordinary

DIBBLE-SOWING AND DATA

1935.

LOWER

SOWING DATE	A	15/2	B	25/2	C	7/3	D	17/3
Locality	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.
Gimmeiza	8.14	52.4	8.88	51.9	7.72	37.2	6.97	24.0
	8.20	39.9	8.10	43.7	7.52	28.8	6.01	19.4
Sakha	6.10	71.7	5.89	64.9	5.73	47.3	5.21	59.5
	5.38	70.8	5.71	63.1	5.87	51.5	5.91	57.5
Siberbai	6.70	54.2	6.63	49.8	6.48	36.4	5.33	33.8
	6.34	47.2	6.63	45.2	5.79	41.2	4.84	27.7
Ez. Khorshid..			4.57	85.0	4.75	86.6	5.24	87.0
			4.70	85.4	4.89	85.0	4.94	86.2
Qaraqis			10.22	70.8	8.98	54.1	8.86	50.9
			9.24	64.6	8.44	51.5	8.48	52.8
Itai-el-Baroud			7.29	71.1	6.35	62.0	7.03	65.7
			6.50	75.0	5.74	64.2	6.37	69.3
Qaha	5.26	88.9	5.34	87.2	4.87	88.0	4.99	80.7
	5.24	89.4	4.94	87.7	4.96	85.2	4.60	80.2
Mit Gaber	8.38		8.55		7.44		6.81	
Hehia	7.14		8.52		7.02		6.18	

UPPER

	A	1/2	B	11/2	C	21/2	D	3/3
Hawaslia	8.41	90.3	7.47	87.4	7.34	87.2	5.03	73.7
	7.29	90.9	5.31	85.6	5.79	86.0	3.63	73.4
Mallawi	11.02	69.6	10.11	64.1	11.23	65.2	11.31	62.7
	11.81	69.2	10.67	65.7	11.99	68.4	12.11	59.1
Kom Ombo			6.10	90.4	6.55	88.4	5.54	84.4
			5.74	88.5	6.07	88.3	5.31	84.2

OF SOWING EXPERIMENTS *(Cont'd.)*

1935.

EGYPT.

E 27/3 Kantars per feddan.	o/o at 1st picking.	F 6/4 Kantars per feddan.	o/o at 1st picking.	Variety	Picking dates	Previous crop	Method of sowing
5.83	16.1	5.50	13.8	Giza 7		Maize	Dibble
5.31	12.0	4.64	10.9				Ordinary
5.87	55.0	5.82	55.5	Sakha	12/9 &	Rice	Dibble
6.12	49.4	5.67	48.4	*	18/10		Ordinary
4.57	22.8	4.39	19.7	Giza 7	10/9 &	Fallow after	Dibble
4.32	21.0	3.63	15.4		21/10	wheat	Ordinary
4.75	84.5	4.06	80.0	Giza 7	17/9 &	Maize	Dibble
4.34	81.9	3.53	77.7		11/10		Ordinary
8.60	44.3	7.33	30.3	Giza 7	8/9 &	Maize	Dibble
7.49	39.0	6.73	29.2		2/10		Ordinary
6.50	60.5	5.69	56.2	Sakha 4	24/9 &	Darawa	Dibble
5.33	60.0	5.13	58.4		2/11		Ordinary
4.17	74.5	3.32	60.3	Giza 12	8/9 &	Maize	Dibble
4.15	72.0	3.37	61.7		25/9		Ordinary
6.44		5.47		Giza 7	Various	Fallow after Berseem	Ordinary
5.47		5.04		Ashmouni	Various	Fallow after Berseem	

EGYPT.

E 13/3		F 23/3					
5.26	77.3	2.57	52.5	Ashmouni	16/9 &	Berseem	Dibble
3.17	68.0	1.57	40.3		18/10	c.c.	Ordinary
10.87	53.5	9.35	31.2	Giza 19	28/8 &	French	Dibble
11.30	49.9	10.18	30.2		11/10	Beans	Ordinary
4.82	77.4	4.14	68.7	Giza 3	23/8 &	Fallow after	Dibble
4.39	74.0	3.91	68.8		1/10	wheat	Ordinary

DIBBLE-SOWING AND DATE

1936.

LOWER

SOWING DATE	A 15/2		B 25/2		C 7/3		D 17/3	
Locality	Kantars per feddan.	o/o at 1st picking,	Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at st picking.	Kantars per feddan.	o/o at 1st picking.
Gimmeiza	8.85	91.5	9.40	8.81	9.81	86.0	9.65	81.8
	8.61	87.3	8.57	85.8	8.70	78.1	8.42	75.9
Siberbai	6.72	84.9	6.37	79.7	5.02	73.2	5.35	73.9
	6.32	83.1	6.02	79.7	5.02	73.7	5.07	73.5
Qaraqis	8.73	52.0	8.54	51.7	8.28	60.9	8.28	50.6
	8.16	54.9	8.28	54.8	8.57	57.8	7.94	52.0
Itai-el-Baroud	6.37	78.5	6.53	83.3	5.92	77.3	5.08	83.5
	6.12	74.7	6.07	74.9	5.41	68.5	4.87	85.4
Kafr Tamboul	7.55		7.53		7.37		7.06	
	6.84		6.75		6.60		6.48	
Qaha	5.61	76.5	5.79	79.8	5.23	76.2	4.82	68.9
	5.48	77.8	6.22	80.4	4.90	67.4	4.24	58.1
Halawat	7.16		7.28		5.94		5.22	
Mit Gaber	8.70		8.80		8.29		7.16	

UPPER

	A	1/2	B	11/2	C	22/2	D	3/3
Mallawi	9.04	78.7	9.93	75.2	10.08	76.1	9.65	69.5
	8.53	78.3	9.65	76.3	10.46	73.5	8.66	65.7
Mataana	9.45	83.9	9.29	83.3	7.59	83.3	7.14	86.1
	7.85	70.9	7.11	67.9	6.70	79.5	6.17	75.7

OF SOWING EXPERIMENTS *(Cont'd.)*

1936.

EGYPT.

E 27/3		F 6/4		Variety	Picking dates	Previous crop	Method of sowing
Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.				
8.13	67.8	8.39	61.6	Giza 12	28/8 &	Berseem	Dibble
7.83	61.5	7.19	54.8		27/9	c.c.	Ordinary
4.11	66.0	3.72	61.2	Giza 7	8/9 &	Fallow after	Dibble
4.29	66.3	3.59	59.9		6/10	wheat	Ordinary
8.13	49.2	6.79	29.4	Giza 7	5/9 &	Rice	Dibble
7.55	42.0	6.38	25.4		4/10		Ordinary
4.54	83.8	3.78	85.2	Sakha 4	29/8 &	Rice	Dibble
4.52	77.5	3.73	77.6		8/9		Ordinary
5.99		5.80		Ashmouni	27/9 &	Rice	Dibble
5.59		5.49			27/10		Ordinary
4.14	58.9	2.94	39.7	Giza 12	21/8 &	Darawa	Dibble
3.78	52.3	2.69	34.9		20/9		Ordinary
4.94		3.82		Giza 7	22/8 &	Berseem	Ordinary
					28/9		
6.27		5.29		Giza 7	1/9 &	Fallow after	Ordinary
					1/10	wheat	

EGYPT.

E 13/3		F 23/3					
9.32	58.6	7.72	42.1	Giza 19	25/8 &	Maize	Dibble
9.52	58.4	8.15	48.0		30/9		Ordinary
4.95		4.49		Giza 12	various	Fallow after	Dibble
4.62		3.61			dates	Millet	Ordinary

DIBBLE-SOWING AND DATE

1937.

LOWER

SOWING DATE / Locality	A 15/2 Kantars per feddan.	A 15/2 o/o at 1st picking.	B 25/2 Kantars per feddan.	B 25/2 o/o at 1st picking.	C 7/8 Kantars per feddan.	C 7/8 o/o at 1st picking.	D 17/3 Kantars per feddan.	D 17/3 o/o at 1st picking.
Gimmeiza	9.23	73.6	9.73	69.6	9.34	67.4	8.47	84.8
	9.21	74.3	9.30	67.6	9.18	63.8	7.77	80.0
Sakha	4.09	75.3	4.16	80.6	4.31	67.6	3.23	57.9
	4.78	77.0	4.90	75.9	4.44	74.3	3.58	55.3
Damanhour	11.94	92.6	11.51	87.9	12.27	89.3	10.79	86.7
	11.97	91.5	11.93	90.4	11.76	88.1	10.62	86.9
Mit Gaber	5.93	74.2	6.08	71.5	5.56	59.2	5.14	50.5
	6.55	67.8	6.57	60.8	6.62	52.8	5.56	48.8
Itai-el-Baroud	7.53		7.72		6.79		6.09	

UPPER

SOWING DATE / Locality	A 1/2		B 11/2		C 21/2		D 3/3	
Mallawi	11.85	73.6	11.64	75.3	11.11	58.2	11.01	59.2
	11.43	71.9	11.51	68.4	10.72	44.6	10.72	48.2
Mataana	11.53	98.2	10.88	93.8	9.82	97.0	8.31	91.3
	9.94	94.5	8.95	96.7	7.62	90.6	6.85	84.0
Sids	7.52		8.32		7.77		7.17	

OF SOWING EXPERIMENTS *(Cont'd.)*

1937.

EGYPT.

E 27/3		F 6/4		Variety	Picking dates	Previous crop	Method of sowing
Kantars per feddan.	o/o at 1st picking.	Kantars per feddan.	o/o at 1st picking.				
8.42	83.7	6.60	65.6	Giza 12	various	Berseem	Dibble
7.49	79.8	6.01	60.4			c.c.	Ordinary
3.99	71.3	3.14	56.0	Sakha 4	9/9 &	Berseem	Dibble
4.16	67.3	3.23	50.6		12/10	c.c.	Ordinary
9.39	81.5	7.15	72.8	Ashmouni	3/9 &	Maize	Dibble
8.93	79.6	5.62	66.9		6/10		Ordinary
4.94	34.0	4.72	28.4	Giza 7	29/8 &	Beans	Dibble
4.89	31.1	4.64	24.8		27/9		Ordinary
5.56		5.12		Sakha 4	7/9 &	Darawah	Ordinary
					12/10		

EGYPT.

E 13/3		F 23/3					
9.10	28.4	8.17	18.1	Ashmouni	18/8 &	Fallow	Dibble
8.57	26.1	7.91	10.2		18/10		Ordinary
7.08	81.5	6.28	73.6	Giza 12	17/8 &	Sugar-	Dibble
5.63	77.4	5.77	64.7		16/9	Cane	Ordinary
7.29		6.77		Giza 19	Various	Maize	Dibble

DIBBLE-SOWING AND DATE

1938.

LOWER

Sowing Date / Locality	A 15/2 Kantars per feddan	o/o at 1st picking	B 25/2 Kantars per feddan	o/o at 1st picking	C 7/3 Kantars per feddan	o/o at 1st picking	D 17/3 Kantars per feddan	o/o at 1st picking
Gimmeiza	6.12	82.8	6.32	85.9	5.95	83.6	5.42	78.1
	5.12	83.5	5.80	83.2	5.04	82.4	5.08	79.2
Sakha	4.49	79.2	4.95	81.2	4.28	79.2	4.40	76.9
	4.83	74.6	4.44	79.0	4.44	77.1	3.98	76.6
Mehallet Roh	7.62	77.2	8.65	82.4	8.00	79.4	7.96	84.0
	7.30	76.3	8.21	81.4	7.17	77.6	7.81	83.7
Itai-el-Baroud	7.53	84.3	7.79	86.4	7.66	87.3	7.32	80.3
	6.60	83.3	7.41	87.4	6.69	84.2	6.43	80.3
Damanhour	6.98	77.0	6.48	79.1	7.24	79.4	7.53	79.8
	6.65	76.4	6.22	79.6	6.48	75.8	5.92	74.2
Mit Gaber	6.39	84.8	6.14	82.8	6.18	80.1	6.14	81.4
	6.05	82.5	5.88	81.3	5.54	76.3	5.54	78.6

UPPER

	A 1/2		B 11/2		C 21/2		D 3/3	
Mallawi	13.42	77.3	13.93	76.0	12.57	73.4	13.46	71.4
	12.78	68.0	13.63	70.5	12.53	69.3	13.04	69.8
Mataana	10.08	95.4	9.19	98.2	7.49	91.5	8.44	94.0
	9.25	86.2	7.55	96.6	5.67	91.8	5.98	92.9

OF SOWING EXPERIMENTS *(Cont'd.)*

1938.

EGYPT.

E Kantars per feddan	27/3 o/o at 1st picking	F Kantars per feddan	6/4 o/o at 1st picking	Variety	Picking dates	Previous crop	Method of sowing
5.14	91.0	4.04	84.2	Giza 12	20/9 &	Maize	Dibble
3.91	86.0	3.36	82.3		31/10		Ordinary
3.97	66.0	3.98	72.3	Sakha 4	17/9 &	Maize	Dibble
3.95	68.1	3.60	63.5		13/10		Ordinary
5.63	67.7	6.98	70.9	Giza 7	25/9 &	Maize	Dibble
5.21	64.2	6.37	72.0		23/10		Ordinary
5.88	75.5	6.52	77.3	Giza 12	12/9 &	Fallow	Dibble
5.38	72.4	5.16	71.3		5/10	after wheat	Ordinary
6.86	61.9	5.93	60.0	Ashmouni	17/9 &	Berseem	Dibble
6.35	69.3	5.16	53.3		11/10		Ordinary
5.67	70.1	3.98	53.2	Giza 7	5/9 &	wheat	Dibble
4.95	65.0	3.47	48.8		3/10		Ordinary

EGYPT.

E	13/3	F	23/3				
11.55	67.0	10.50	58.1	Giza 19	30/8 &	Fallow	Dibble
12.02	65.5	11.89	63.0		9/10	after wheat	Ordinary
6.73	89.9	6.05	89.5	Giza 12	5/9 &	Fallow	Dibble
6.16	93.2	6.16	91.0		10/10		Ordinary

DIBBLE-SOWING AND

1934

LOWER

Locality	Giza 7	Giza 12	Giza 19	Giza 24	Giza 25
Gimmeiza	7.07	6.45	6.51	6.89	6.73
	5.84	5.61	5.64	5.46	5.76
Motamadiya	7.00	6.47	6.24	5.95	5.52
	6.56	5.61	5.61	5.54	5.23
Kafr-el-Sheikh	4.64	4.64	4.66	2.91	4.42
	4.39	4.28	4.35	3.81	4.17
Siberbai	3.03	3.20	2.96	3.09	2.98
	2.72	2.96	2.62	2.91	2.48
Kufur-el-Raml	8.42	8.91	7.93	8.59	7.81
	7.96	8.46	7.76	7.83	7.09
Mehallet Subk	7.66	8.76	7.99	7.02	6.64
	6.34	6.79	6.51	4.80	5.21
Qaha	5.08	5.63	5.21	5.21	4.53
	5.25	6.31	5.76	5.46	4.87

VARIETY EXPERIMENTS.

1934.

EGYPT.

Maraad	Fouadi	Sowing date	Picking dates	Previous crop	Method of Sowing
6.33	6.64	—	—	—	Dibble
5.67	5.82				Ordinary
5.73	6.05	—	—	—	Dibble
5.04	5.97				Ordinary
4.35	4.73	—	—	—	Dibble
4.09	4.53				Ordinary
2.35	2.84	—	—	—	Dibble
2.11	2.62				Ordinary
7.91	7.36	—	—	—	Dibble
7.19	6.92				Ordinary
7.17	6.89	—	—	—	Dibble
5.48	5.10				Ordinary
4.70	4.83	—	—	—	Dibble
4.87	4.95				Ordinary

DIBBLE-SOWING AND

1935.

LOWER

Locality	Giza 7	Giza 12	Giza 19	Giza 24	Sakha 4
Gimmeiza (1)	7.17	7.47	8.09	5.17	4.50
	5.53	5.83	6.49	4.14	3.59
Gimmeiza (2)	4.21	3.12	5.02	3.20	2.45
	2.56	3.12	3.06	1.95	1.45
Mehallet Subk	4.66	5.07	5.63	3.70	2.77
	3.81	4.06	4.83	3.01	2.26
Mit Khalaf..	6.17	6.49	6.66	5.77	4.90
	5.94	6.28	6.07	5.31	4.82
Qaha	5.52	5.44	5.27	5.52	4.34
	5.57	5.16	5.14	5.10	3.92

1936.

LOWER

	Giza 7	Giza 12	Giza 19	Giza 26	Giza 27
Gimmeiza	8.95	8.93	8.46	7.66	7.55
	7.93	7.51	6.48	6.73	6.33
Kafr Tamboul	7.07	7.51	6.09	5.89	6.13
	5.95	5.97	5.46	4.84	5.64
El-Balamone	10.45	9.73	8.67	7.87	9.23
	7.57	8.99	5.90	6.81	8.27
El-Kattawia	8.51	9.27	7.62	6.98	7.02
	8.04	8.46	6.98	6.86	6.98
Shebin-el-Kom . ..	6.83	8.00	7.17	6.03	5.79
	6.70	7.13	6.92	5.98	5.37
Moushtohor	10.63	9.43	10.15	7.94	7.70
	9.52	9.03	8.21	6.58	6.74
Qaha	5.19	4.99	5.55	3.85	4.36
	4.66	4.51	4.74	3.23	3.64
El-Hassania	5.61	5.69	6.02	3.79	4.37
	4.96	4.83	5.17	3.38	4.05

VARIETY EXPERIMENTS *(Cont'd.)*.

1935.

EGYPT.

Maraad	Fouadi	Sowing dates	Picking dates	Previous crop	Method of sowing
5.73	6.30	11 / 3	21/9 &	Maize	Dibble
4.19	4.59		7/10		Ordinary
3.12	3.36	11 / 3	21/9 &	Maize	Dibble
1.96	2.13		7/10		Ordinary
3.28	4.19	4 / 3	12/9 &	Maize	Dibble
2.58	3.30		11/10		Ordinary
5.90	5.90	17 /2	31/8 &	Maize	Dibble
5.59	5.56		2/10		Ordinary
5.04	5.65	25 /2	5/9 &	Maize	Dibble
4.44	5.08		25/9		Ordinary

1936.

EGYPT.

Sakha 4	Maraad				
6.63	7.71	15 /3	26/8 &	Berseem	Dibble
5.78	6.73		27/9	c.c.	Ordinary
5.67	5.70	15 /3	19/9 &	Rice	Dibble
4.55	4.53		27/10		Ordinary
7.83	8.76	24 /2	13/9 &	Maize	Dibble
5.46	7.42		20/10		Ordinary
5.80	7.28	9 / 3	18/9 &	Berseem	Dibble
5.21	6.52		1/10		Ordinary
5.88	6.32	27 / 2	22/8 &	Maize	Dibble
5.22	5.90		29/9		Ordinary
7.77	7.87	24 / 2	31/8 &	Berseem	Dibble
6.69	7.03		22/9		Ordinary
3.47	3.65	25 / 2	24/8 &	Maize	Dibble
2.82	3.15		21/9		Ordinary
3.56	3.80	23 /2	17/8 &	Berseem	Dibble
3.07	3.45		19/9	c.c.	Grdinary

DIBBLE-SOWING AND

1937.

LOWER

Locality	Giza 7	Giza 12	Giza 26	Giza 30	Sakha 4
Gimmeiza	8.82	10.08	6.80	9.46	6.97
	8.31	9.44	6.64	8.96	6.72

UPPER

	Giza 7	Giza 12	Giza 19	Giza 31A	Giza 31B
Mallawi	12.19	10.41	11.89	11.13	11.22
	11.02	10.11	11.63	10.51	10.45
Mataana	10.36	12.11	10.81	9.11	11.93
	6.12	7.18	6.47	6.57	7.89

1938.

LOWER

	Giza 7	Giza 12	Giza 26	Giza 29	Giza 30
Gimmeiza	4.80	6.96	4.03	5.28	5.04
	2.57	5.45	2.51	3.76	3.43
Anboutein	6.90	9.24	6.26	6.36	6.82
	6.10	8.57	5.12	5.70	6.38
Mit Gaber	7.32	6.98	5.97	6.35	6.89
	6.09	6.86	4.71	6.22	6.05

UPPER

	Giza 7	Giza 12	Giza 19	Giza 31A	Giza 31B
Mallawi	7.92	7.87	9.50	8.94	9.22
	7.26	7.14	7.67	8.08	8.43
Mataana	8.58	8.69	9.65	8.84	9.17
	7.62	7.09	8.10	8.71	8.41

VARIETY EXPERIMENTS *(Contd.)*.

1937.

EGYPT.

Maraad	Bahtim Abiad	Sowing date	Picking dates	Previous crop	Method of sowing
8.66	8.49	9 / 3	31/8 &	Berseem c.c.	Dibble
8.25	7.61		5/10		Ordinary

EGYPT.

		9 / 2	18/8 &	Fallow after	Dibble
			1/10	Wheat	Ordinary
		26 / 2	19/8 &	Fallow after	Dibble
			18/9	Sugar-cane	Ordinary

1938.

EGYPT.

Sakha 4	Bahtim Abiad				
1.43	6.05	25 / 3	20/9 &	Rice	Dibble
0.92	4.40		25/10		Ordinary
3.68	7.56	26 / 2	7/9 &	Maize	Dibble
3.04	6.60		3/10		Ordinary
4.91	6.56	24 / 2	5/9 &	Fallow after	Dibble
4.32	6.05		4/10	Wheat	Ordinary

EGYPT.

		27 / 2	3/9 &	Fallow after	Dibble
			21/10	Wheat	Ordinary
		26 / 2	3/9 &	Fallow	Dibble
			10/10		Ordinary

ORGANIC CONTENT OF SOILS OF THE MIDDLE EAST

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The title of this paper may be somewhat misleading since its subject matter is largely derived from investigations and experiments carried out on the alluvial soils of Egypt alone, after less than three years in Kenya. Nevertheless, the picture drawn from them should be of general interest where similar conditions exist, i.e. where irrigation agriculture is practised in a hot climate with little rain. In addition, no work similar in scope has been carried out on the organic matter content of any other body of soils in the Middle East.

It may be emphasized here that the number of observations made on any one aspect has almost always been such as to enable discussion of differences to take place on a statistical basis. The sites of the manurial experiments with cotton, for example, which average in number about thirty a year, are well distributed throughout the country (see Fig. 1), and the results of these experiments can be shown to be a reasonable reflection of what actually happens in ordinary cultivation (Fig. 2).

Land under the basin system of irrigation in Egypt—by which is here meant land that has never been under summer cultivation—is nowadays only a small proportion of the total cultivated area, but this residue of survival from the practice of past centuries is invaluable as a representation of the original state of land which is now perennially irrigated. Basin land soils are thus defined as «normal» and any departure from their condition in perennial land will represent changes due to the alteration of the system of irrigation and cropping. Below are given the average contents of organic matter and total nitrogen, and the average « carbon to nitrogen » ratios at different levels in fourteen profiles from basin land, and in twenty-four profiles from perennial land:—

Table 1.

Depth of layer (cm.)	Basin land (Average of 14 profiles)			Perennial land (Average of 24 profiles)		
	Organic matter per cent.	Total nitrogen per cent.	Ratio carbon-nitrogen	Organic matter per cent.	Total nitrogen per cent.	Ratio carbon-nitrogen
0—25	1.31	0.065	11.8	1.45	0.074	11.4
25—50	1.21	0.054	13.0	1.10	0.053	12.1
50—75	1.09	0.050	12.7	0.98	0.044	13.0
75—100	1.09	0.050	12.6	0.91	0.039	13.6
100—125	1.05	0.048	12.7	—	—	—

From the figures in the table it is clear that the *subsoils* of land under perennial irrigation are becoming steadily poorer in organic matter, and especially in total nitrogen. The decrease of these with depth, already evident in basin land, is very marked in perennial. Moreover, it is a notable fact that in both types of land the organic matter content is a characteristic feature of each profile so that the amount present in any one layer can be taken as an index to that which will be found in the others. This is demonstrated in Fig 3, where the total nitrogen in the 75—100-cm. layers has been plotted against that in the 50—75-cm. ones. The diagrams show that the points in basin land group themselves well about the line of equality, whereas with perennial land they are displaced to one side of the equality line, in consequence of the more abrupt decrease with depth. The diagram also shows that the original diversity of basin land has become much reduced under perennial irrigation, and the organic matter contained in the subsoils of the latter can be regarded as in process of moving towards one common (low) level.

As regards the *surface* (0—25-cm.) layers, the figures in table 1 show perennial land to be richer in organic matter and total nitrogen than basin land, but the number of observations is too small to establish this probability as a fact. A better appreciation of the situation is obtained by considering (Fig. 4) the difference between frequency distributions of the total nitrogen content of the surface (0—25-cm.) and of the sub-surface (25—50-cm.) layers in 110 profiles of perennially irrigated land. These include those of table 1. The distribution at the surface shows marked positive skewness, whereas in the deeper layer it is symmetrical. Perennial land is therefore receiving additions of organic matter to a varying extent; and it can be concluded that under the system of agriculture practised it is on the whole no poorer, and can even be richer in organic matter than the basin land from which it was converted.*

The above general presentation has been supplemented by subjecting the organic matter in selected profiles from both series in table 1 to fuller examination. The results in all cases show this organic matter to be, as would be expected in an advanced state of decomposition. Thus celluloses are either absent altogether, or present only in very small amounts ; they can only have a fugitive existence under Egyptian conditions. Two main fractions account for nearly all the organic matter: (a) Lignin and resistant protein (70 to 90 per cent.) and (b) Hydrolysable protein (10 to 30 per cent.). The first fraction in particular is very resistant to further change; the second is more easily decomposable and forms the more immediate reserve of nitrogen for plant growth. The hydrolysable protein fraction is more abundant in the surface layers of perennially irrigated land than in their sub-soils, and is the result of the organic matter additions already referred to.

The total nitrogen contained in Egyptian soils is small compared with that found in such soils as those of humid temperate regions. Nevertheless, it does provide a substantial part of the nitrogen required for the production of full crops, and under certain circumstances it may even be entirely adequate for that purpose. To obtain an estimate of the nitrogen available two separate determinations are made in the laboratory on the soil samples taken from the manurial experiments. The first is a measure of what is called the « soluble » (ammoniacal and nitrate) nitrogen, and the second measures the « hydrolysable » nitrogen. The latter is what is brought into solution by heating the soil under standard conditions with dilute suphuric acid ; it may be regarded as a measure of the mobilizable nitrogen present, in addition to the ammoniacal and nitrate nitrogen. The two fractions together form the « available » nitrogen. The amount of this present in any soil depends in the first place on the total nitrogen (as would be expected) and in the second on the length of time it has lain fallow, i.e., the length of the period of drying and heating to which it has been subjected prior to sampling.

The effect of Sharaki (or fallowing) in increasing the available nitrogen, and the proper treatment of fallowed land so as to obtain the greatest benefit

* The average total nitrogen contained in these 110 surface samples works out at 0.082 per cent. This amount is roughly equivalent to 900 kilos. of nitrogen per acre of 25 cm. depth.

to the following crop, are of sufficient interest to justify a digression to deal with them. In 1934 two plots of land at Giza, 1/40th of an acre, one after berseem and the other after wheat, were left as bare fallow all summer. Composite surface samples to a depth of 15-cm. were taken from them at weekly intervals for fifteen weeks beginning on June 26th. The increases in ammoniacal and nitrate nitrogen which took place during the period are given below:—

	Ammoniacal and nitrate nitrogen (p.p.m.)	
	After berseem	After wheat
Average for first three samplings	10.6	8.1
Average of last three samplings	35.1	14.3

Smaller but similar increases in available nitrogen are found in dried samples during storage.

These increases in « ammoniacal and nitrate nitrogen » are increases in the ammoniacal part; no increase in nitrate can take place since bacterial activity is entirely arrested under such dry conditions. And the essential thing in the treatment of fallow land in Egypt is that bacterial activity (by irrigation) should not be reintroduced too soon before the planting of the succeeding crop, otherwise a considerable part of the benefit will be lost. The following results of an experiment at Giza show that a watering given about a month before the planting of the crop reduces available nitrogen and therefore the yield.*

Plot No.	Date of Sharaki Watering	Date of Watering for Land Cultivation	Date of Sowing	Yield in Ardebs per Feddan
A1	—	10/7	17/7	10.0
B1	26/6	—	17/7	12.4
A2	—	17/7	31/7	14.3
B2	26/6	17/7	31/7	10.6
A3	—	31/7	14/8	13.4
B3	26/6	31/7	14/8	9.1

In another experiment at Giza with maize, alternate strips (the « B » plots in the table below) were given a watering after fallow on the 21st of June; all plots then received a ploughing-watering on 15th of July and the crop was sown on the 1st of August (yields are in ardebs per feddan).

Yields in Ardebs per Feddan

Plot No.	After Berseem	Plot No.	After Wheat
A1	10.15	A4	8.7
B1	8.4	B4	7.3
A2	9.8	A5	7.0
B2	8.1	B5	5.9
A3	12.1	A6	6.5
B3	9.9	B6	5.9
		A7	6.3
		B7	5.4

*The ardeb of maize=140 Kg. or 308 lb. A feddan is an acre, nearly.

From these figures it is clear that the June watering of the fallow has consistently reduced the yield and that the reduction is greater in the richer land.

Two field experiments with cotton designed to measure the amounts of nitrogen that may thus be lost have shown that on land rich in available nitrogen a watering given a month before sowing brought about a loss equivalent to rather more than one sack* of fertilizer per feddan, while on poorer land the loss was between one-half and three-quarters of a sack per feddan. The « loss » is not a permanent one; it occurs through some of the nitrogen being converted by bacterial action to more unavailable forms which will only slowly again become available.

Owing to this continuous variation in the state of the organic matter and nitrogen present, it is not surprising to find that estimates of available nitrogen made in connection with manurial experiments, if they are to bear any relationship to the yields recorded, must be made on soil samples taken at strictly specified times. Thus maize experiments must be sampled within the week before sowing. The sampling of cotton experiments on the other hand must take place at thinning time, which is when any manure given is usually applied; comparisons made against samples taken at sowing time can have no meaning. Also, it is essential that the nitrogen determinations should be made as soon as possible after the soils reach the laboratory.

The utility of nitrogenous fertilizers in these manurial experiments does not, of course, depend solely on the amount of nitrogen available in the soil, although it is naturally an important factor. For example, if we compare the three very dissimilar crops of cotton, wheat and rice, the only one that can be regarded as even approaching to conventional behaviour in its response to added nitrogen is wheat: low-yielding land under wheat tends to respond more than land which is already high-yielding (Fig. 5). With cotton this result is turned inside-out; Fig. 7 shows that large returns from fertilizer nitrogen applied to cotton can only be expected where a high level of yield already exists. Rice again is different from either wheat or cotton in that success is not so much dependent on nitrogen as on the presence in the soil of sufficient amounts of organic matter which is easily decomposable (Fig. 6).

The main factors deciding the level of yield of cotton are physical properties of the soil (which affect the water intake of the root system) and the nature of the season; nitrogen can only act in a secondary manner within the limits set by these factors. The nature of the season is of particular interest. In Fig. 8 the yields of control plots, together with the maximum increases given by nitrogen, have been plotted against sowing date for individual experiments in the *Delta* for the five years, 1933 and 1936—1939. The mean maximum temperatures experienced in March are given for each of these years. It is clear that marked stimulation of early boll production in the Delta by the addition of nitrogen is only possible when advantage can be taken of such warm spring weather as happened in 1936 and 1937 to sow early. In the other three years, with their colder springs, the principal effect of sowing date is on the yields of the control plots. The picture given by the diagram is not complete, since it is possible to have still lower March temperatures; early sowing would then become positively prejudicial. Cold springs of this kind occurred in several of the years prior to 1914, and the opinion was then (correctly) formed that the nitrogenous manuring of cotton in the Delta did not pay. In upper Egypt on the other hand, with a warmer climate, nitrogenous manuring of cotton will always be useful.

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*One sack of fertilizer means 100 kilos. of nitrogenous fertilizer containing 15 1/2 kilos. of nitrogen.

The fact that the nature of the season decides what kind of response will be obtained from added nitrogen can also be illustrated by the amounts of available nitrogen present at sowing and at thinning in the 1938 and 1939 cotton experiments:—

Available nitrogen in p.p.m.*

Depth of layer (cm.)	At Sowing				At Thinning			
	1938 Av. of 21 expts.		1939 Av. of 30 expts.		1938		1939	
	NH3-N + NO3-N	H.N.	NH3-N + NO3-N	H.N.	NH3-N + NO3-N	H.N.	NH3-N + NO3-N	H.N.
C.S.S.	18.6	19.4	22.6	18.8	69.3	22.1	37.0	19.6
0— 25	18.2	18.8	14.0	17.6	23.6	18.6	14.4	18.4
25— 50	7.0	11.4	6.5	12.0	11.1	12.8	8.5	12.2
50— 75	5.7	9.4	5.5	10.6	8.1	10.6	6.3	11.0
75—100	5.6	8.5	5.2	9.4	7.2	10.0	5.3	9.9
Totals	55.1	67.5	53.8	68.4	119.3	74.1	71.5	71.1

*p.p.m.=parts per million : the figures for a 25 cm. layer may roughly be regarded as kilos. per acre. C.S.S.=Composite surface sample. HN=Hydrolysable nitrogen.

Although the average content of available nitrogen at sowing time was roughly the same in both years, it became very dissimilar a month and a half later. The soils in the 1938 experiments, after the colder spring, contain very much larger amounts of ammoniacal and nitrate nitrogen than in 1939, all layers of the profiles being affected. In both years control plot yields are positively correlated with the ammoniacal and nitrate nitrogen, and the increases from fertilizer nitrogen shows a negative correlation with the hydrolysable nitrogen, present at thinning. These relationships are consistently more pronounced in 1939, as a consequence of the greater need for nitrogen in the warmer year, In neither year can the nitrogen available at sowing be related to yield.

SUMMARY

The changes taking place in the properties of perennially irrigated land are compared with the basin land from which it was converted, with particular attention to changes in the organic matter.

The sub-soils of perennial land are being steadily depleted of organic matter and especially of nitrogen. The surface layers, as against this, under the system of agriculture practised, are at least no poorer and may be richer in total nitrogen than those of basin land. The organic matter in both types of land is in an advanced state of decomposition.

The methods of estimating the available nitrogen are given and the factors controlling its amount discussed.

Benefit from nitrogenous fertilizers is shown not only to depend on the amount of available nitrogen already present in the soil, but also (a) on the crop grown, and (b) on the kind of weather experienced.

Fig. 1

DISTRIBUTION OF THE 1936 COTTON MANURIAL EXPERIMENTS IN THE DELTA (27 EXPTS)

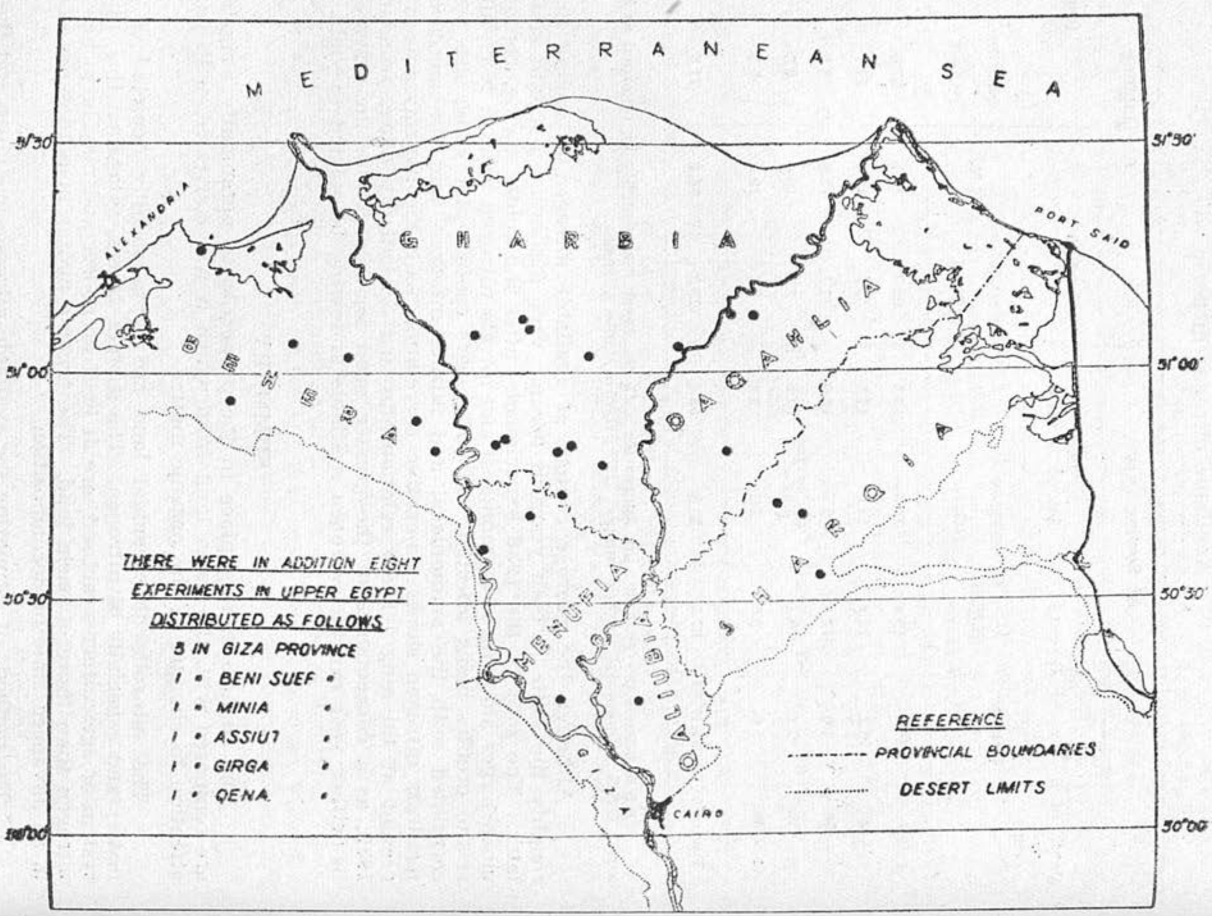


FIG. 2

COMPARISON OF YIELDS IN COTTON EXPTS WITH AVERAGE YIELDS FOR EGYPT

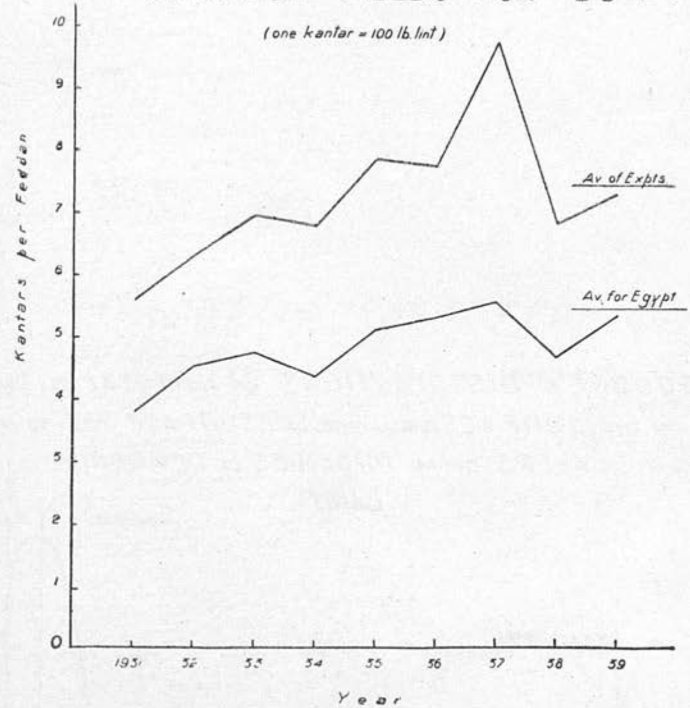


FIG. 3

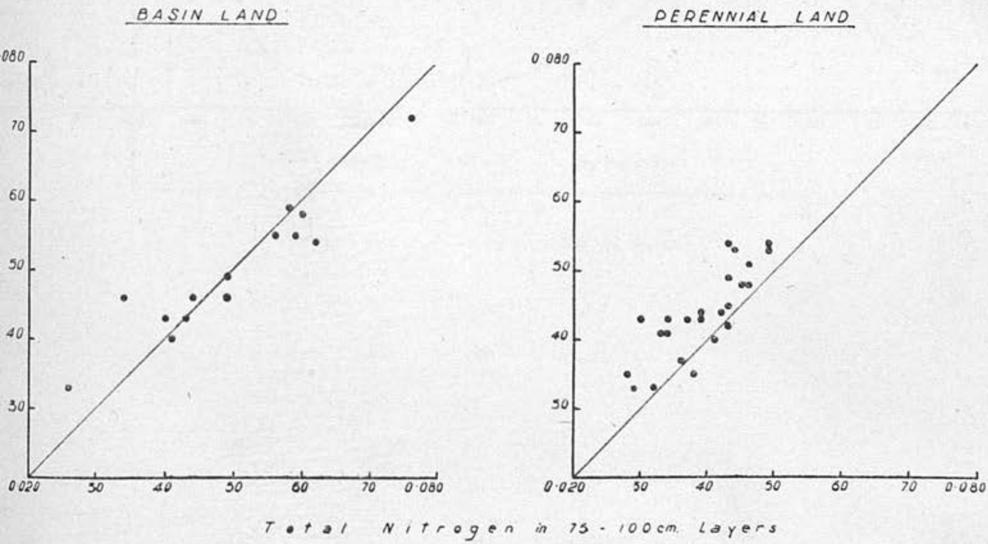


FIG. 4

FREQUENCY DISTRIBUTIONS OF THE TOTAL NITROGEN IN THE SURFACE (0-25 cm.) AND SUBSURFACE (25 - 50 cm) LAYERS OF 110 PROFILES OF PERRENIAL LAND

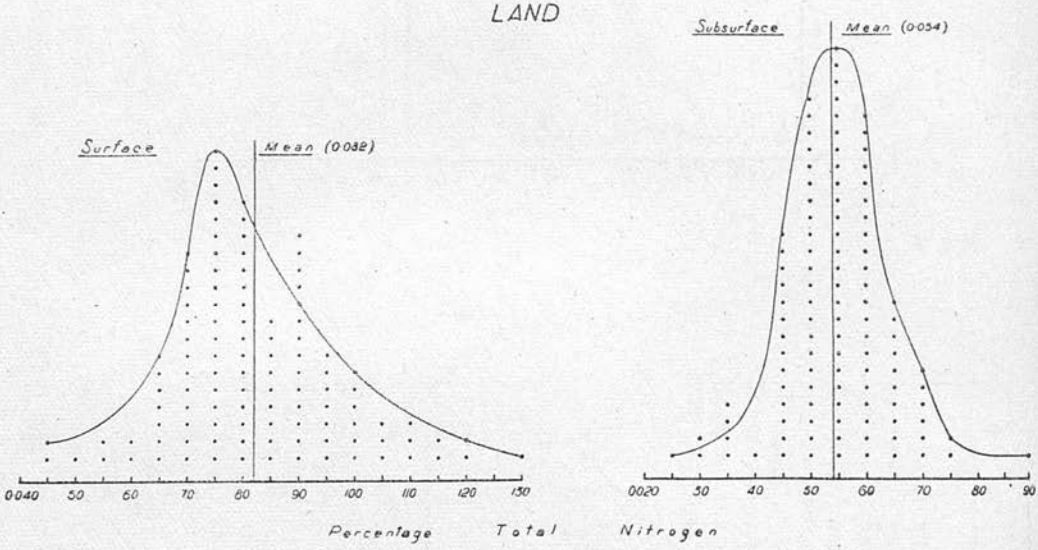


FIG. 5

THE 1937 WHEAT EXPERIMENTS

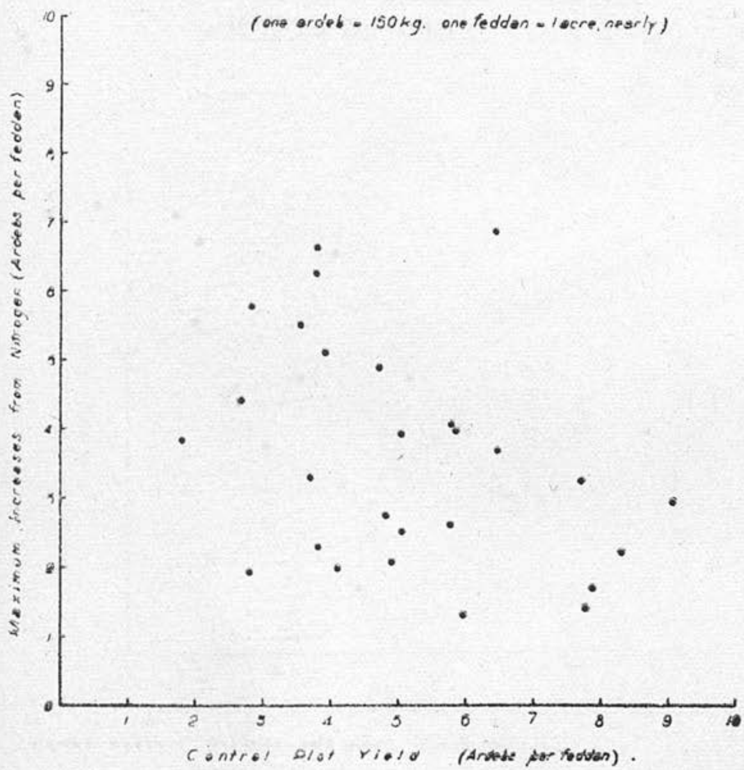


FIG. 6

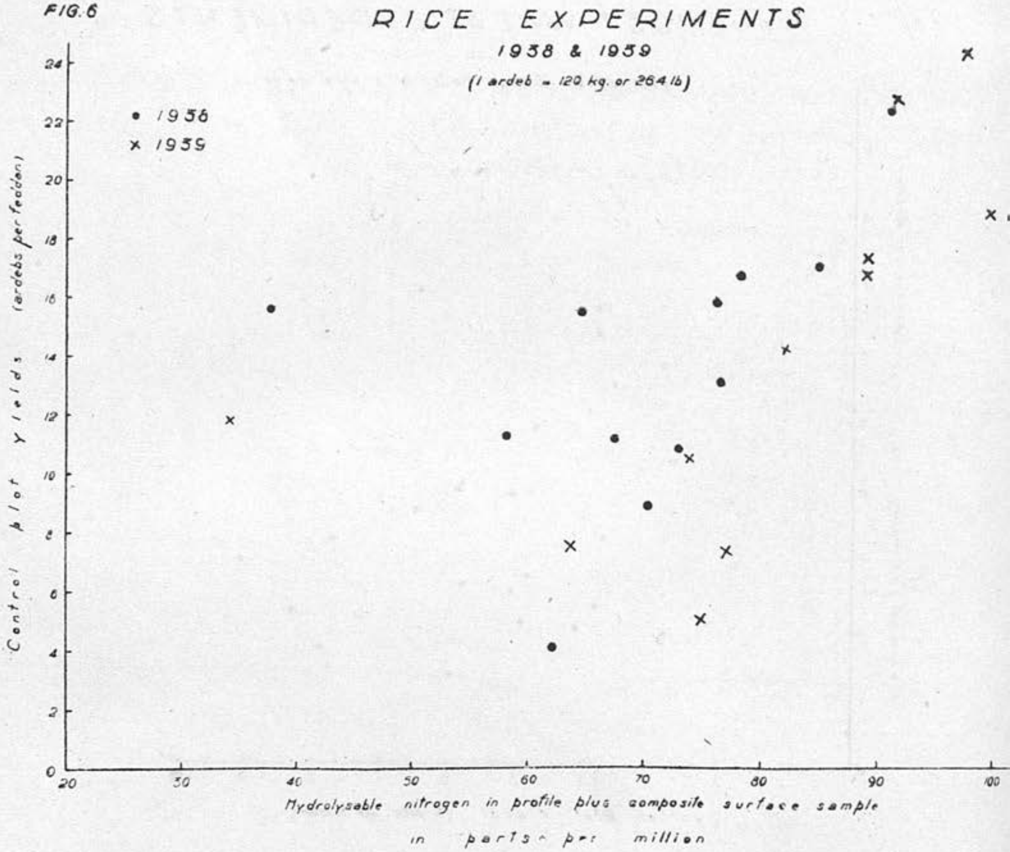

RICE EXPERIMENTS
1958 & 1959
(1 ardeb = 120 kg. or 264 lb)
• 1958
× 1959
Control plot yields (ardebs per feddan)
Hydrolysable nitrogen in profile plus composite surface sample
in parts per million

Fig. 7

COTTON EXPERIMENTS 1931-39

RELATION BETWEEN CONTROL PLOT YIELD AND RESPONSE TO MANURING

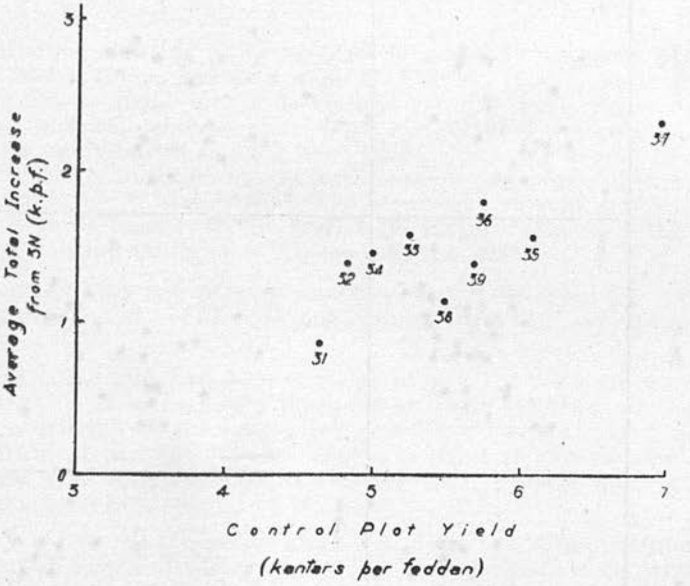
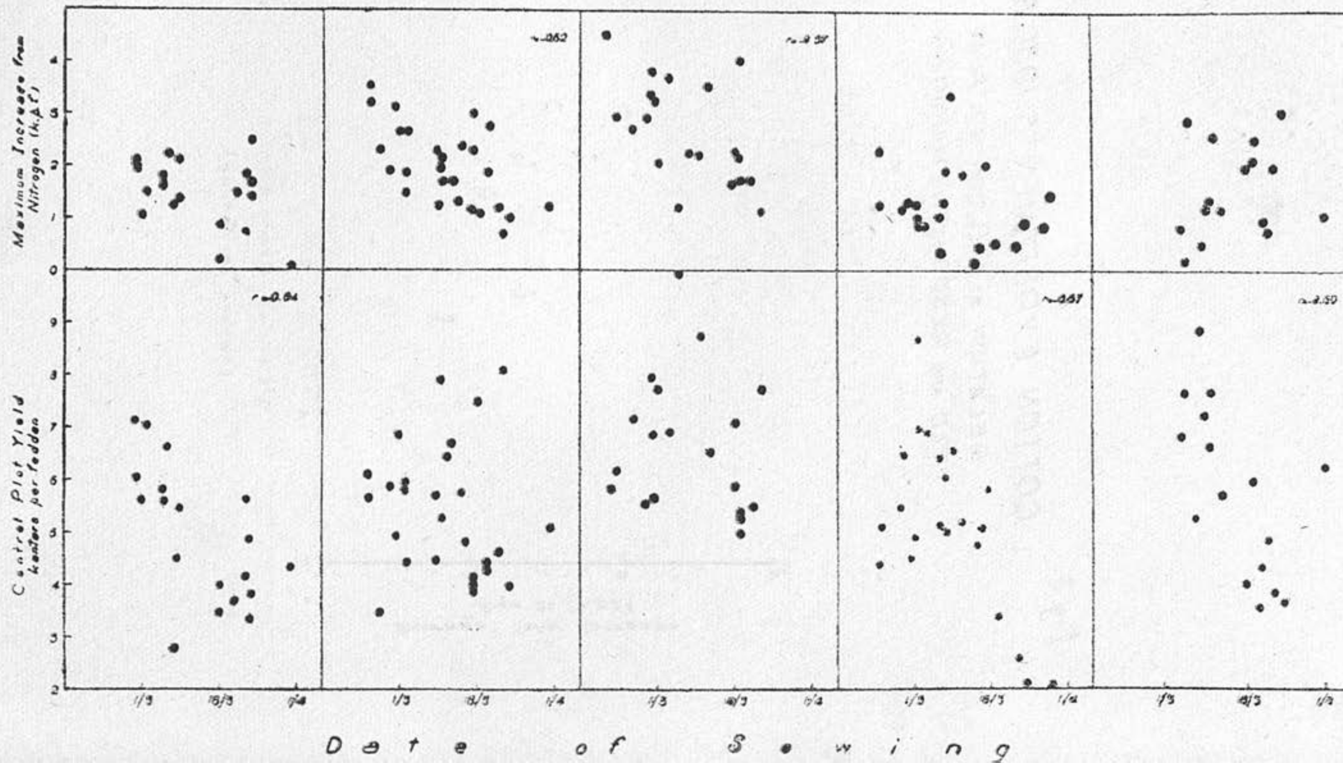


FIG. 8 SOWING DATES AGAINST CONTROL PLOT YIELDS AND AGAINST MAXIMUM INCREASES FROM NITROGEN
(DELTA ONLY)

YEAR	1933	1936	1937	1938	1939
MEAN MAX. TEMPS. IN MARCH (°C)	25.6°	25.1°	25.6°	24.5°	23.9°



DISCUSSION

Dr. Keen (Scientific Advisory Mission to M.E.S.C.): I feel that this paper is particularly important not only for Egyptian conditions (that is self-evident) but also for conditions in a number of adjoining countries.

It is the kind of work that I feel needs doing because it is, in a sense, re-examination of certain standard ideas, developed from western European agricultural science in the light of the very different climatic and moisture regimes that exist in practically rainless irrigated warm countries, like Egypt. We have already had in the session of which this paper forms a part, evidence of the marked difference in cultivation practices between the two regions. This paper brings out marked differences in the organic matter regime in the two types of climate mentioned.

The same scientific principles apply. It is merely their manifestations which are different. The first is this very interesting change in the organic matter content of the soil when it is converted from perennial to basin irrigation.

In the top layer of perennial irrigated soils the organic matter is not only maintained but may even be increased—that is one point.

The second point which Mr. Gracie has naturally not dealt with in detail in his paper but one which is present in our minds is—what is the optimum organic matter content for soils in the sub-tropics, particularly in soils that are irrigated?

The practice of using dung for fuel is generally regarded as a bad one. It may be a bad practice, but as a scientist I would like to be more convinced than I am at the moment that it is essential to put more organic matter into these tropical and sub-tropical soils. The rate of disappearance is very great indeed, and its oxidation in the soil is in effect a burning away. Can it be that the peasant cultivator in these regions is sub-consciously aware of that and prefers to burn his manure in a useful way? The economic problem is this: is the value of the extra organic matter, in the brief time that it remains in the soil, worth the expense of putting the organic matter into the soil?

I do not express any opinion one way or the other—what I ask for as a scientist is experimental results and not opinions based on analogies which may be false.

Another point that hangs on that one is: what is the main function of the organic matter? Is it to maintain the good physical structure of the soil or to supply plant nutrients. If the latter, there are other ways of supplying nutrients than in the form of organic matter. That is a point of considerable importance and we cannot give sound advice on this question without more experimental evidence of the kind brought out in Mr. Gracie's paper.

These seem to me the points that arise from Mr. Gracie's interesting and not unprovocative paper. How much organic matter ought to be returned to the soil; what is the fate of that organic matter; and what is its function? Is it primarily that of supplying nutrients?

Mr. Eyre (Palestine): I would like, if I may, to add one further point to the three or four that Dr. Keen has raised. He mentioned the fact that our peasants have possibly realized that it is not worth while manuring land which is cultivated under their own old forms of agriculture. Many of these tools and old forms of agriculture are now being changed entirely and we have had quite a good deal of discussion in regard to deep ploughing, which is a fairly recent introduction to peasant agriculture in these parts, and the fact that these old systems are now be.ng altered might possibly lead to a different conception of the value of working manures into our soils.

Dr. Balls (Egypt): I merely want to direct the attention of the Middle East to a curious meteorological fact that is not widely known. It came up in Mr. Gracie's paper and I want to give it back to you. The mean annual temperature of Egypt has risen in the last 30 years by the amount of 2 deg. Cent.

This is only a temporary change and it will undoubtedly move down again. It reacts on most processes and most particularly on sowing. The date of sowing for cotton is at least three weeks earlier than it was 30 years ago. Last year the spring was identical with that of 1913—I saw the figures. The result was that people sowed their cotton at the usual time and it was resowed and resowed. In the Middle East one must expect a reversion back to these old days. What you say today may not be true in 10 years time.

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service

CHEMICAL SECTION

Bulletin No. 249

Evaluating the Effect of Nitrogenous Fertilisers by Combining Statistical and Agronomic Data

BY

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GOVERNMENT PRESS, CAIRO, 1948

Government Publications are on sale at the " Sale Room ", Ministry of Finance. Correspondence relating to these publications should be addressed to the " Publications Office," Government Press, Bûlâq, Cairo.

Price . . . . . P·T. 20

Conversion table for weights and measures used

1 Feddan = 4200.8 sq. metres = 1.038 acres.

1 Kantar of cotton (ginned) = 100 rotls = 99 lb.

The ardeb of wheat = 150 kg.

The ardeb of rice = 292.5 kg. (undec. rice).

The ardeb of maize = 140 kg.

The ardeb of barley = 120 kg.

In the response curves 1N = 100 kg. nitrogenous fertiliser supplying 15.5 kg. nitrogen.

MINISTRY OF AGRICULTURE, EGYPT

Evaluating the Effect of Nitrogenous Fertilisers by Combining Statistical and Agronomic Data

The dearth of shipping resources during the years 1939-1946 made it desirable to collect information as to how far Egypt was dependant for food production upon artificial manures, the imports of which had been increasing during the previous twenty years though they were almost unknown at the beginning of the century.

Two sources of information were available, both useful in themselves, but more than doubly useful when combined. To take a simple example: it was known from the experimental records of the Agronomic Section that the average effect of one tenth of a ton of nitrate applied directly to wheat was to raise the yield by rather more than one quarter of a ton (1.8 ardebs). This quantity of wheat would occupy considerably more shipping space than that taken up by the nitrate which produced the extra wheat, so that it was obviously more economical to use shipping space for importing nitrate (to help Egypt feed herself) than to bring in wheat as such. This left unanswered the question as to what fraction of the imported nitrate normally went to wheat and the other food crops? The "Annuaire Statistique" could not provide this information directly, but by combining its data with the Agronomic facts it was possible to infer this, and other desirable pieces of knowledge. The present account summarises the conclusions thus reached.

The tons of nitrogenous fertilisers imported each year from 1911 to 1940 are shown in figure **1***a*. During that period they were at a minimum of 3,601 tons in 1918 and reached a maximum of 566,362 tons in 1937. The latter figure was largely accounted for by nitrate of soda (262,397 tons), nitrate of lime (197,862 tons), and nitrochalk (58,399 tons) the balance being made up of sulphate of ammonia (16,341 tons), "ammonium nitrate" (25,021 tons), nitrosulphate of ammonia (5,634 tons), cyanamide (708 tons) and potash salts (1,207 tons). It is assumed that the nitrogenous fertilisers shown as imported in any one year were wholly consumed in the course of it and their amount has been divided by the total area under cotton, maize, millet, rice, wheat and barley in that (fertiliser) year to give a figure, in tons per thousand feddans (or kilograms per feddan), which is called the intensity of nitrogenous manuring (fig. **1***b*). These two figures **1***a*and **1***b*as well as figs. **2 - 5** and figs. **13***a*, **13**b and **19** giving the areas and average yield of the different crops have been drawn on logarithmic paper. This has been done to give an idea of rates of increase or decrease since equal vertical distances on a logarithmic scale mean equal percentage differences. The figure for tons per thousand feddans can then be translated into terms of kantars or ardebs per feddan by making use of the average results of the various series of manurial experiments conducted during 1931 - 1940. The intensity of manuring was greatest in 1937 when it reached almost 97 tons per thousand feddans and least in 1918 when it was practically zero.

It should be noted that the level of yield in these manurial experiments is higher than for the country as a whole. Nevertheless, the experiments include a range sufficient to show that the effect of nitrogen is probably somewhat underestimated in the cereal experiments where low-yielding land tends to respond more than high-yielding, and is possibly overestimated with cotton where the opposite holds good. The results of the cotton experiments are a reasonable reflexion of what happens in ordinary cultivation.

CEREAL CROPS

The curves for the average yields of wheat, rice, maize and barley for 1913 - 1940 (figs. **2 - 5**) all show a marked rise in the latter part of the period reviewed. The rise can however only be associated straightforwardly with the contemporary increase in the amounts of fertilisers imported for the case of wheat.

Wheat

Of these four cereal crops the average yield of wheat has alone been more or less independant of the total area devoted to it (fig. **6***a*) so that the relationship between yield and intensity of manuring shown by figure **6***b* is taken as real. The intensity of manuring has accordingly been converted to ardebs per feddan by making use of the response curve (fig **7***a*) obtained from the 1935-1936 to 1940-1941 manurial experiments and is shown as the dotted line in the lower part of figure **7***b* (the yield increase from the first 100 kilos of 15½ per cent fertiliser in these experiments is 1.8 ardebs per feddan). In the upper part of figure 7b the unbroken line is a five - year

NITROGENOUS FERTILISERS IMPORTED

FIG.1a

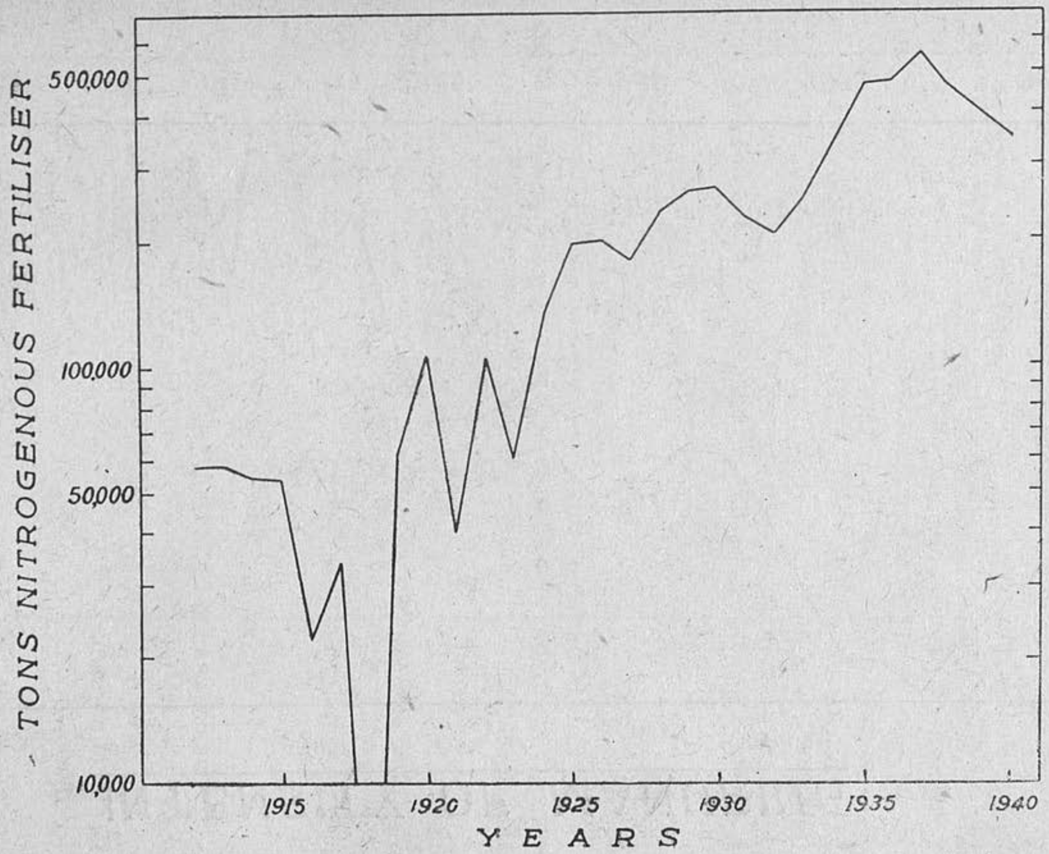


FIG. 1b

INTENSITY OF MANURING

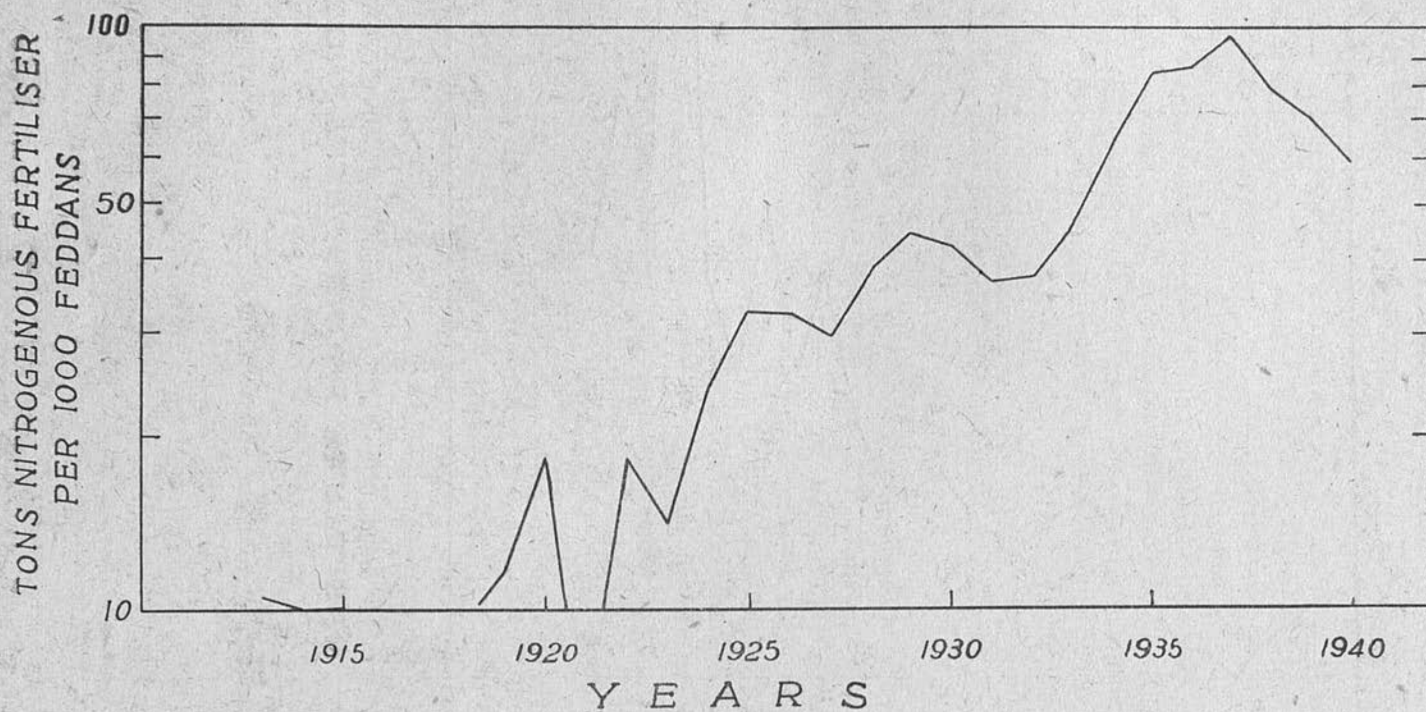
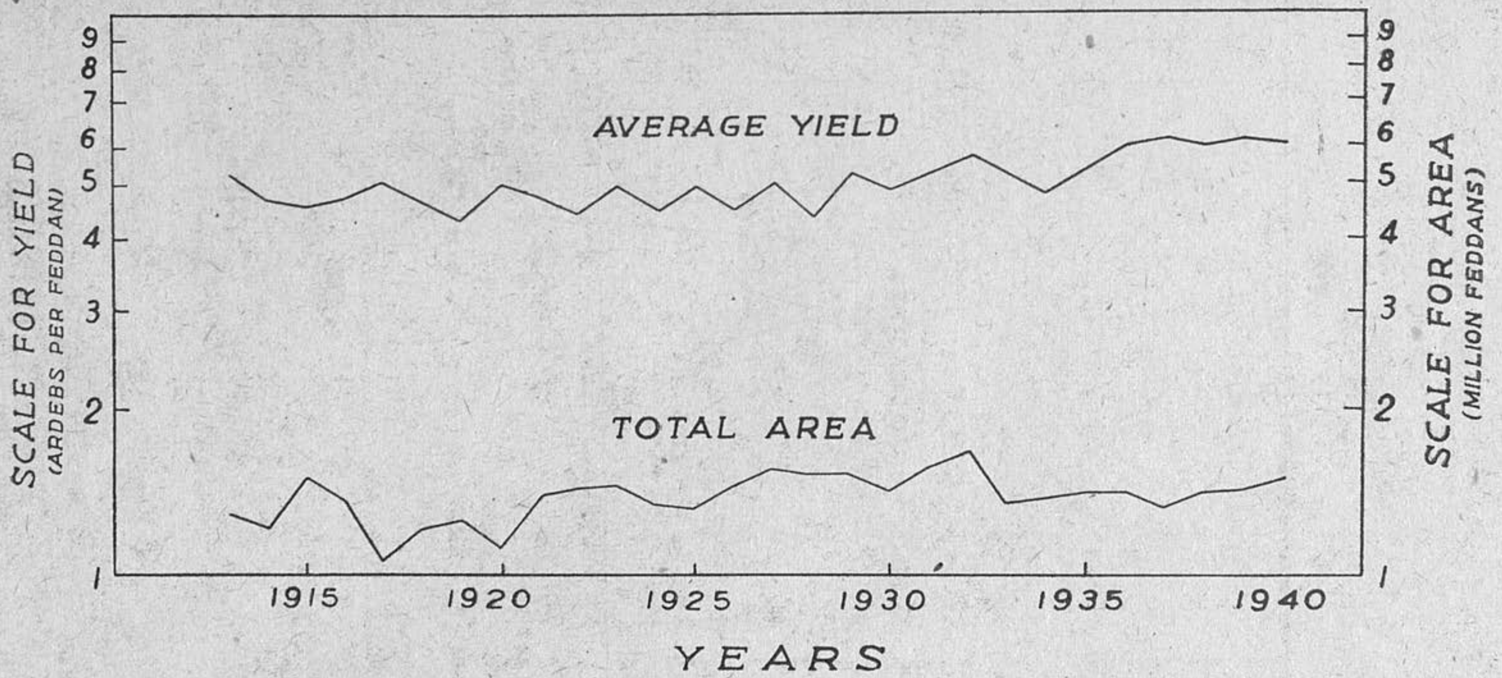


FIG.2

WHEAT
1913 - 40

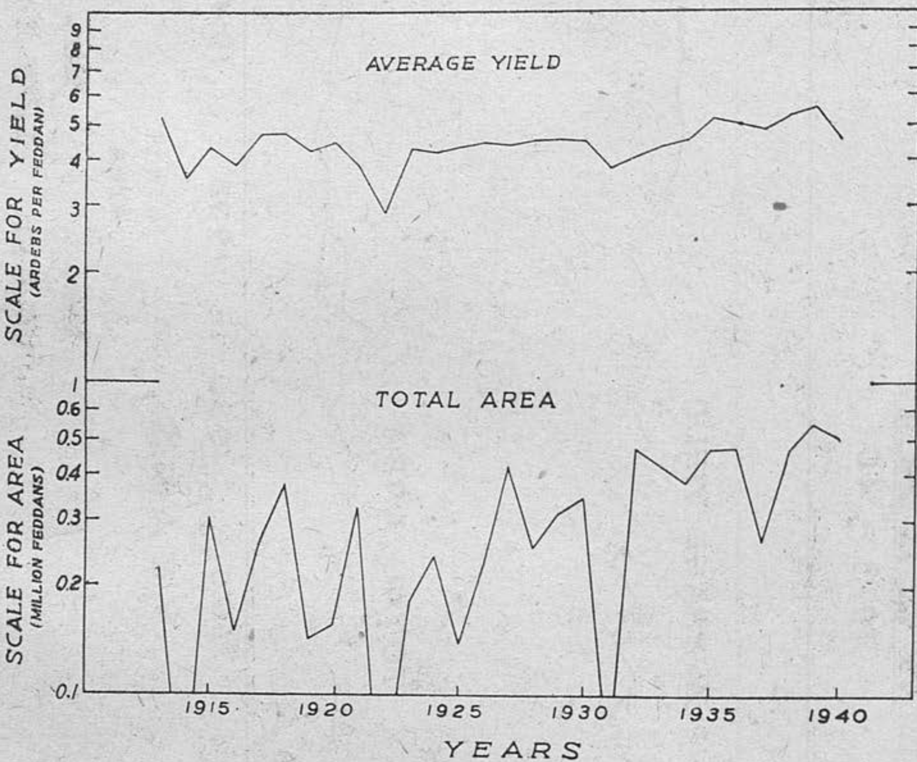


Av. Yield		Area	
Min.	Max.	Max.	Min.
4.29	6.15	1,697,413	1,075,587

RICE

1913 - 40

FIG. 3

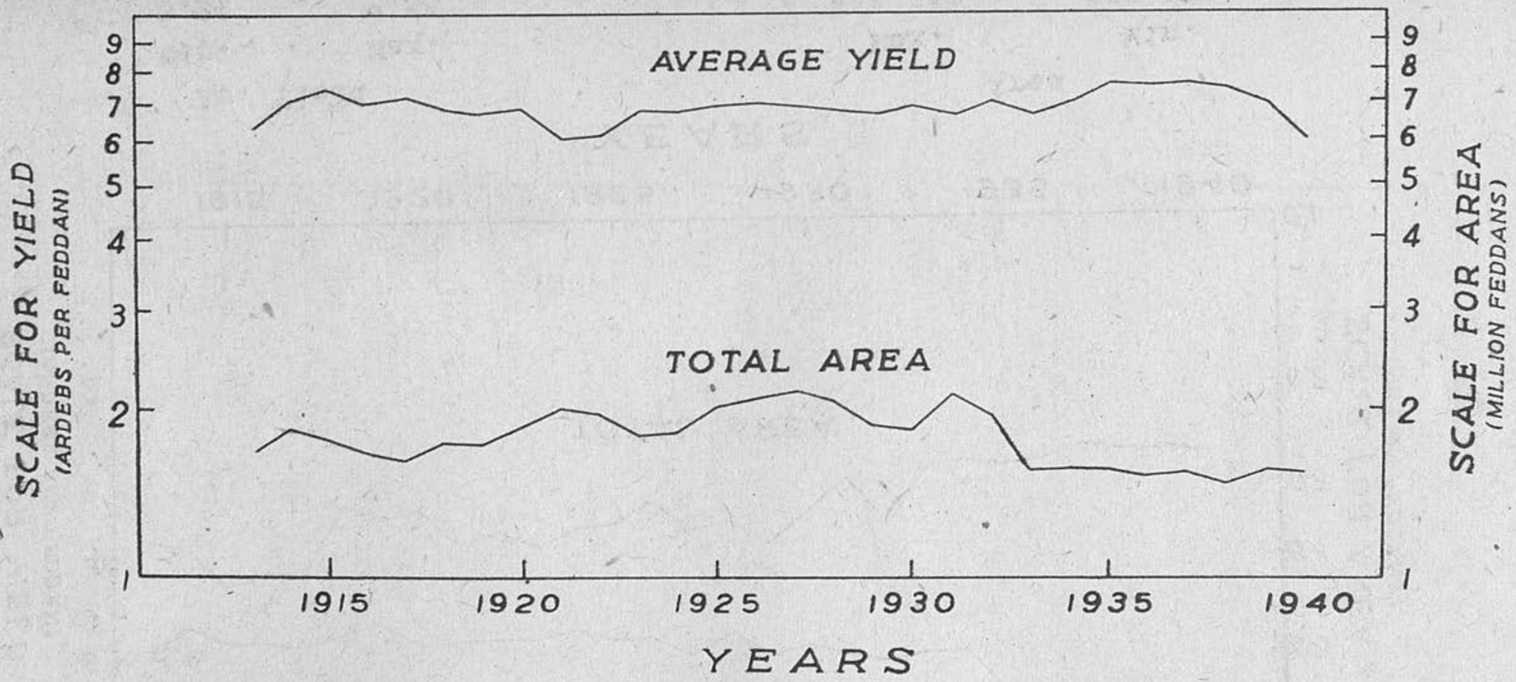


Av. Yield			Area	
Min.	Max.		Max.	Min.
2.88	5.52		546,870	42,549

FIG. 4

MAIZE

1913 - 40

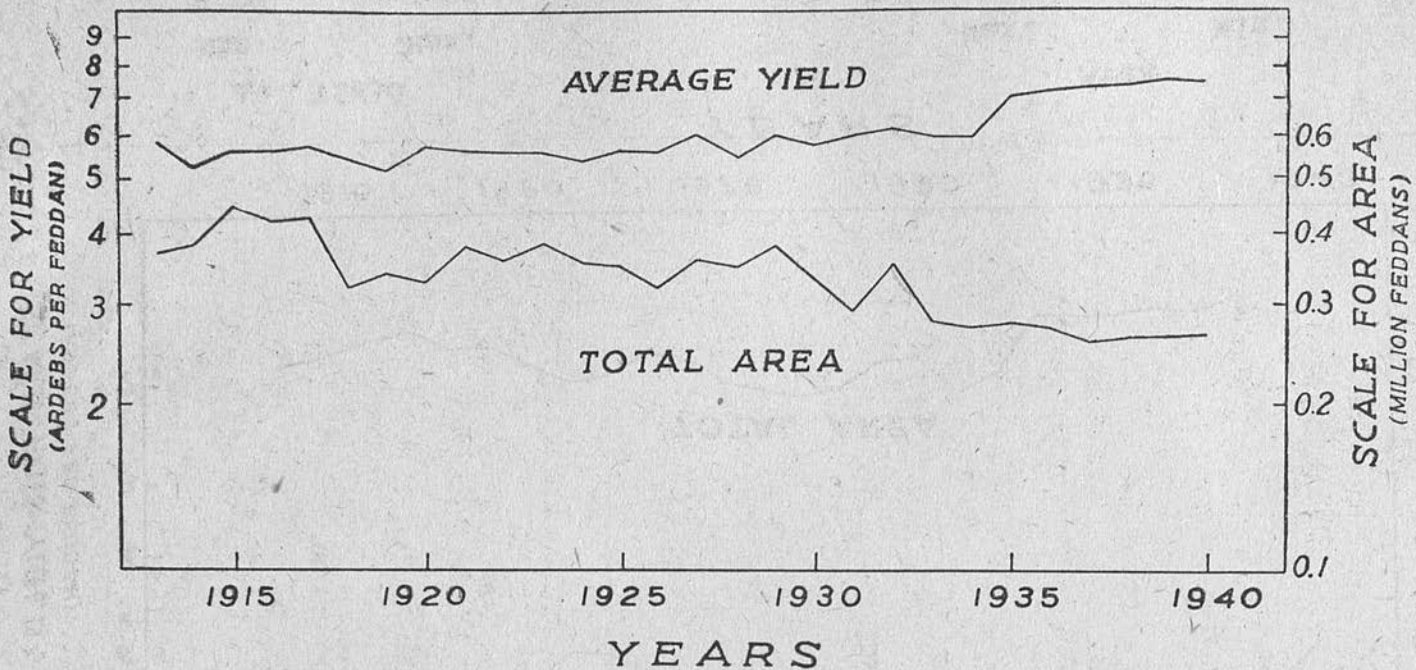


Av. Yield			Area	
Min.	Max.		Max.	Min.
6.07	7.66		2,133,220	1,497,086

FIG.5

BARLEY

1913 - 40



Av. Yield		Area	
Min.	Max.	Max.	Min.
5.24	7.55	445,643	260,976

WHEAT
1913-40

FIG. 6a

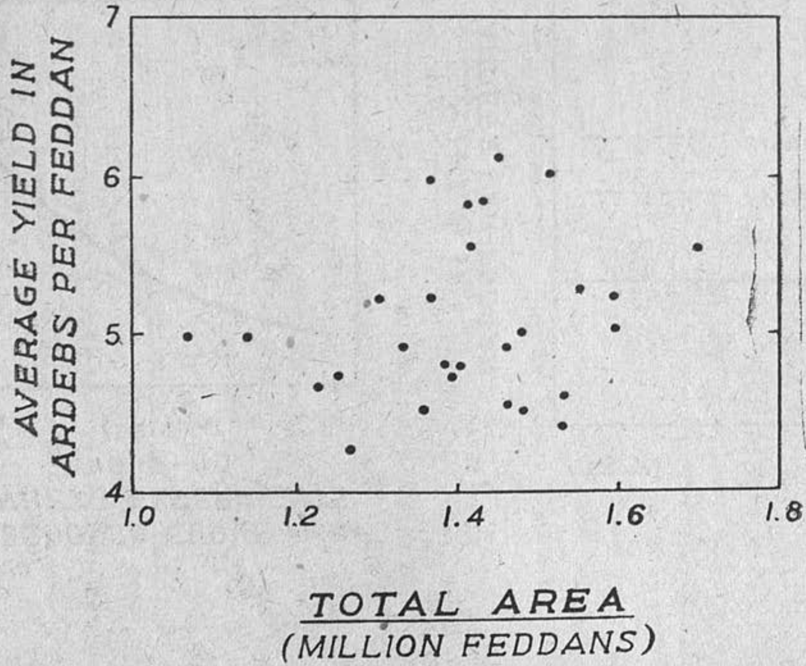
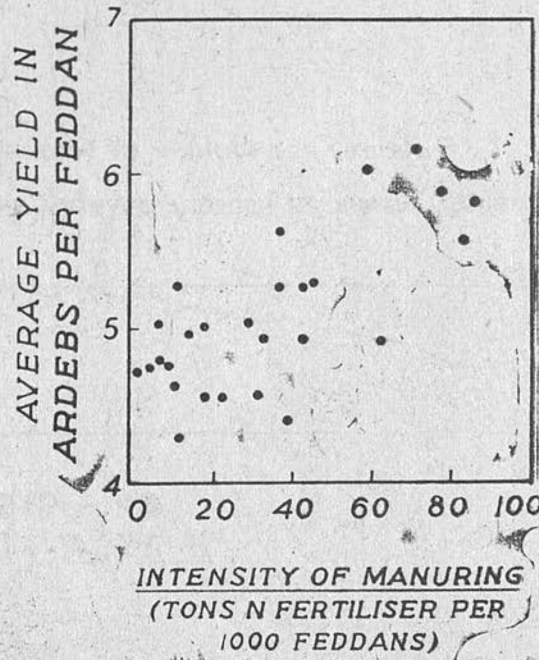
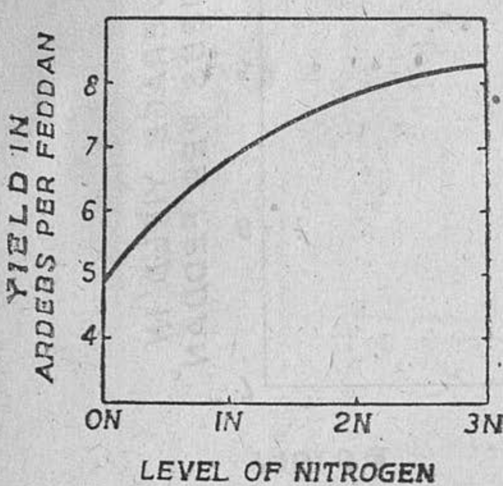


FIG. 6b



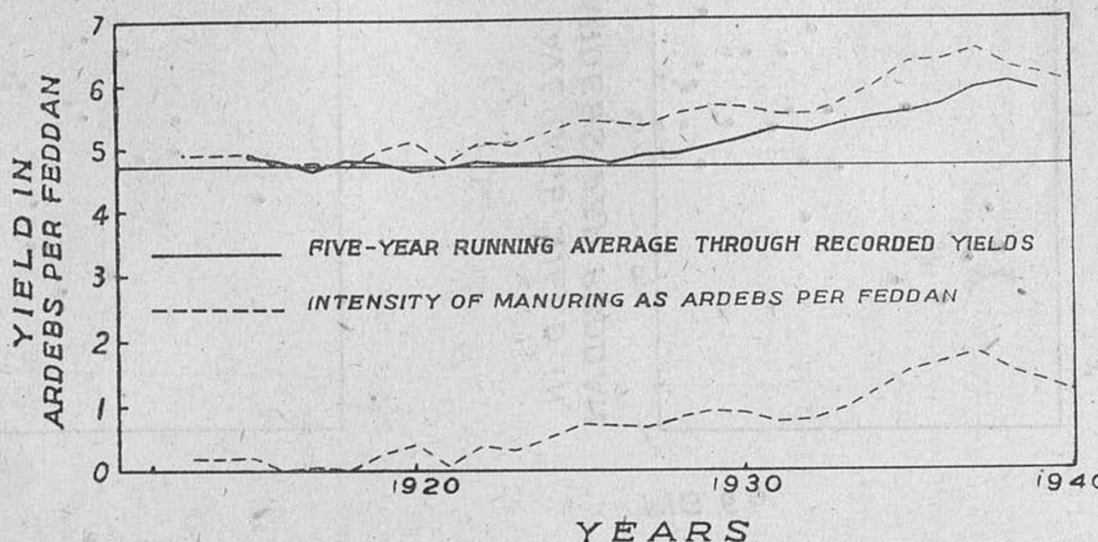
RESPONSE CURVE FROM WHEAT EXPERIMENTS
1935 - 40
(138 Expts.)

FIG. 7a



WHEAT
1913 - 40

FIG. 7b



running average through the recorded wheat yields. It shows that with little or no imported fertiliser available the average yield for the country, with seasonal variation eliminated, would be about 4.75 ardebs per feddan. The yield curve corresponding to the intensity of manuring derived from the response curve has therefore been raised to 4.75 as the base line for "no manure". The parallelism between the two curves is very good; the one inferred from the intensity of manuring lies always consistently above actual experience. It is concluded that the wheat crop *as a whole* has never benefited from more nitrogen than is equivalent to about 1.24 ardebs, or 60 kilos of nitrogenous fertiliser per feddan. This would include any residual effects of direct applications to the cotton, which it usually follows in the crop rotation. It may actually of course have received rather more if uneven distribution be allowed for — thus wheat grown under typical basin land conditions, i.e. without pump irrigation, receives no nitrogenous fertiliser.

Rice

This crop offers a complete contrast to wheat in that the total area devoted to it has been the principal factor in deciding what the yield per feddan will be (fig. **8***a*). This is reasonable because, the area under rice being determined by the summer water available before the flood, extension of it will mean extension to better land and the possibility of a higher yield; contraction gives the reverse. That the area devoted to it is on the whole greater (and the yield per feddan higher) after 1932 is a natural consequence of the second heightening of the Assuan Dam and the construction of Gebel Aulia Dam.

The years 1935, 1936, 1938 and 1939, when the total area and average yield were both highest, were also years of high intensity of manuring. The points for these four years occupy similar positions — the top right hand — in diagram 8a where yield is set against area and in figure **8***b* where it is plotted against manuring intensity, thus offering the suggestion that nitrogenous manuring may have had some share in the high average yield of these four years. The total correlations between yield and area, between area and intensity of manuring, and between intensity of manuring and average yield work out respectively at + .62 + .59 and + .51. The corresponding partial correlation coefficients are + .47 + .40 and + .23. The main relationship is therefore between total area and average yield; the associations between intensity of manuring and area or yield must be regarded as having been coincidental.

RICE
1913-40

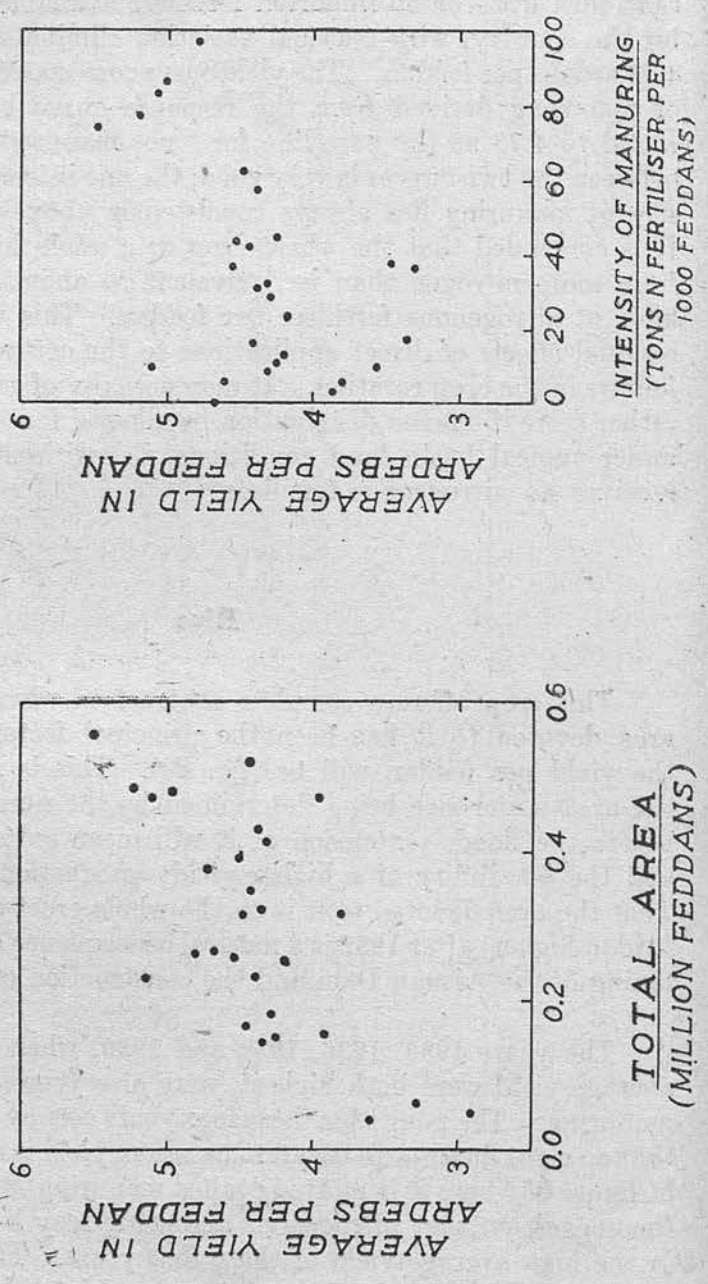


FIG. 8 a

FIG. 8 b

Maize

The outstanding features brought out by figure 4 for the maize crop are the sharp and maintained (to 1941) drop in the total area under it which occurred in 1933 and the accompanying rise (at first in 1933 but especially in 1934 and 1935) in the average yield. The decrease in total area was consequent on the fall in maize prices, so that the increased average yield per feddan might be due in part to the crop being confined to better land, as well as to an increased use of fertiliser. Figure **9**a shows that these two features together mean that the negative relationship, already existing, between total area and average yield is strengthened, as also is the positive one between intensity of manuring and yield shown by figure **9**b. The latter diagram brings out a further feature of the figures for the maize crop, in that the average yields for the five war years 1914 - 1918 are unduly high in relation to the intensity of manuring. The total correlations for the whole twenty-eight years from 1913–1940 between yield and intensity of manuring, between intensity of manuring and area, and between average yield and area work out respectively + .60, — .46 and — .45. If the five war years 1914–1918 are dropped from the calculations the association between yield and intensity of manuring improves to + .86, that between area and intensity of manuring to — .62 while the one between total area and yield is very little changed at — .46. The corresponding partial correlations are + .82, — .48 and + .16. The main relationship is clearly that between average yield and intensity of manuring; the influence of area on yield becomes quite insignificant when the factor of manuring is eliminated. On the other hand the negative partial relationship between area and intensity of manuring (average yield eliminated) remains significant. The increased use of fertiliser may therefore have been a factor in maintaining the total area under the crop roughly constant up to 1941 at the low figure to which it had fallen in 1933 in consequence of the fall in prices.

The maize crop has accordingly been treated in the same way as the wheat, the intensity of manuring being converted into ardebs per feddan by making use of the response curve (fig. **10**a) drawn from the results of the 154 field experiments carried out in the years 1932–1939. In figure **10**b the dotted line in the lower part shows the ardebs per feddan so obtained, while the unbroken line in the upper part is a five-year running average through the recorded yields. This latter curve is at a minimum of 6.52 ardebs per feddan in 1920 and 1921, when little fertiliser was available, and a maximum of 7.47 in 1936. It was the first of the cereal crops to be affected by the rising intensity of manuring; it shows the influence on yield first in 1924, with a

MAIZE
1913-40

FIG. 9 a

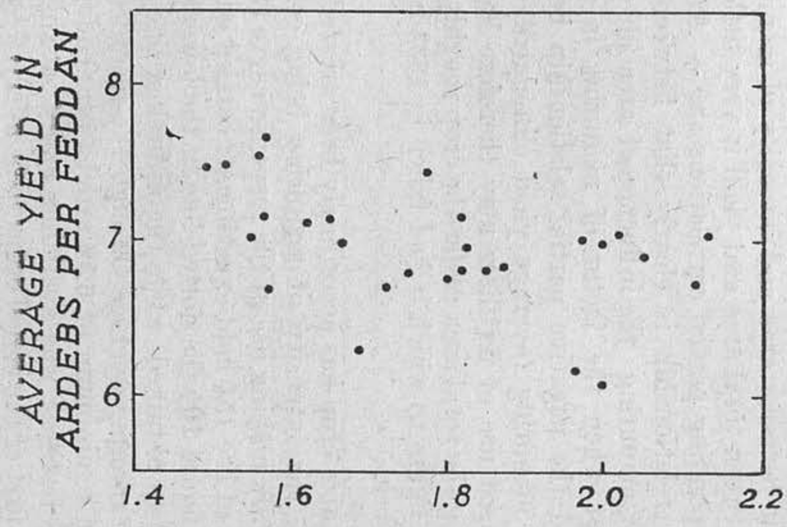
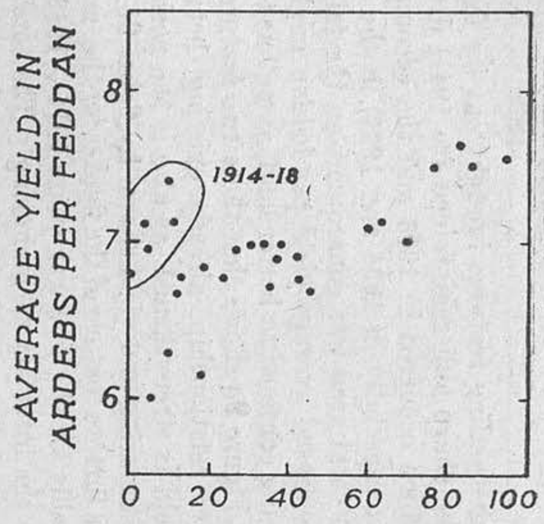
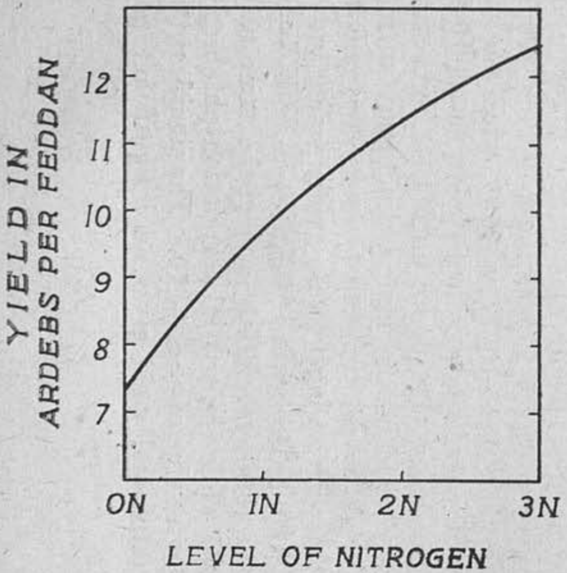


FIG. 9 b



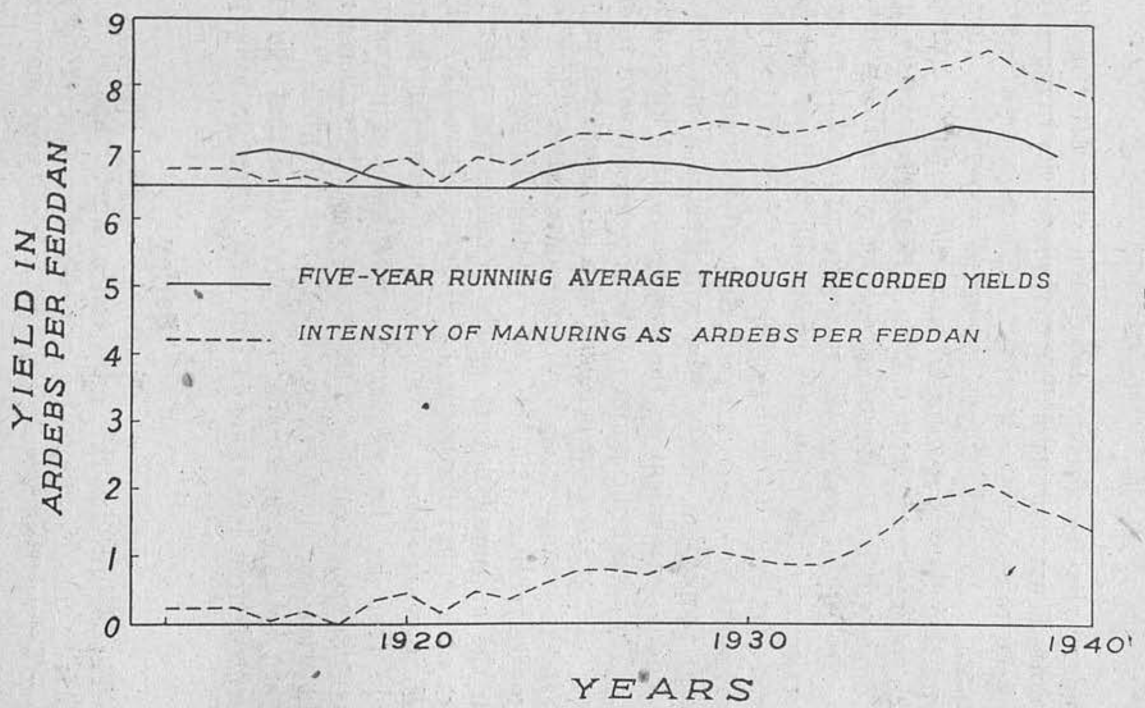
RESPONSE CURVE FROM MAIZE EXPERIMENTS
1932 - 39
(154 Expts)

FIG. 10 a



MAIZE
1913 - 40

FIG. 10 b



secondary rise (as already noted) ten years later in 1934 and 1935. The dotted curve corresponding to the intensity of manuring has therefore been raised to the level of 6.52 ardebs as a base line for "no manure." As with wheat, recorded experience runs parallel to but much below that inferred from the fertiliser nitrogen imported. If the total increase from 6.52 to 7.47 ardebs of 0.95 of an ardeb be put down wholly to the increased use of fertiliser this would mean, using the initial part of the response curve, that maize has received a maximum of 38 kilos of nitrogenous fertiliser per feddan; this is almost certainly an under-estimate. None of the maize in these experiments received farmyard (beladi) manure whereas in practice a large proportion of the crop will receive about 200 donkey loads per feddan, equivalent on the average to 15.5 kilos of fertiliser nitrogen. The remaining maize not receiving farmyard manure is mainly grown after permanent berseem, and is represented in its due proportion in the average given by the response curve. If it is assumed that all maize receives 15.5 kilos of available nitrogen as beladi manure, then the appropriate part of the response curve for measuring the effect of fertiliser nitrogen is that lying above 1N. The 0.95 of an ardeb increase shown by the smoothed curve for the recorded yields would then be the equivalent of 54 kilos of nitrogenous fertiliser. When allowance is made for the maize grown after berseem, (amounting to between one third and one quarter of the whole) these 54 kilos will in turn be an overestimate; it is concluded that the crop will have benefited from less than 54 but more than 38 kilos per feddan.

Barley

The figures for this crop tell a story that is in general quite similar to that for the maize crop, i.e. there is a strong positive correlation between average yield and intensity of manuring and there are weaker negative ones between area and intensity of manuring and between area and average yield. Figure 5 shows that the area under the crop was at a maximum of over 400,000 feddans in the three war years 1915-1917; in 1933, when the sharp decrease in the maize area also took place, it drops below 300,000 feddans and continues increasingly below this figure until 1941. As with the maize crop, the average yield in the same period went up markedly in 1935 so that the negative relationship between area and yield is strengthened (fig. **11**a), as also is that between average yield and intensity of manuring (fig. **11**b). The main association is again between the last two factors, the total correlation having the same value as for maize at $r = +.85$ while the partial correlation obtained by the elimination of area has a value of $r = +.70$. The significant negative correlation between area and yield gives an insignificant partial coefficient of

BARLEY
1913-40

FIG.IIa

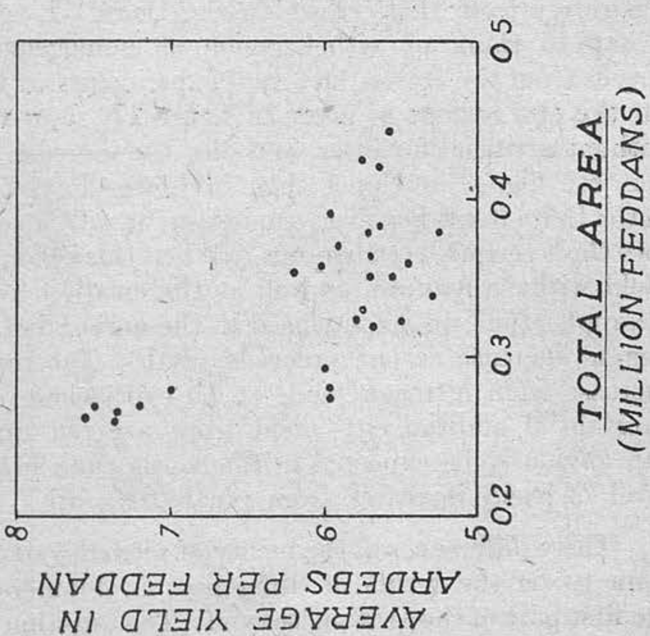
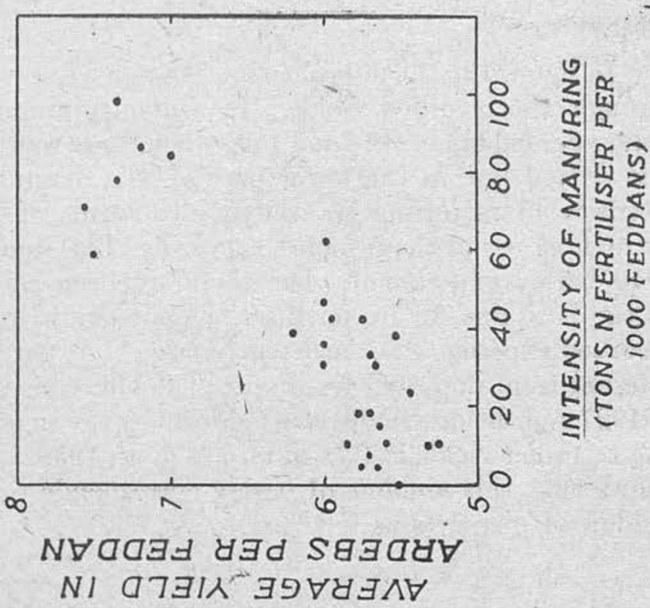


FIG.IIb



— .16 when intensity of manuring is eliminated, while the partial correlation between area and intensity of manuring is barely significant at — .39.

In figure **12***b* the unbroken line is again a five-year running average through the recorded yields. It is at a minimum of roughly 5.61 ardebs per feddan in 1918 and 1920 when there was little or no fertiliser. The dotted line in the lower part of the diagram, which gives the intensity of manuring translated into terms of ardebs per feddan by making use of the response curve (fig. **12***a*) derived from the 1935-1940 barley experiments, has therefore been raised to 5.61 ardebs as the base line for no fertiliser. Again, as with wheat and maize, recorded experience is consistently *below*, but parallel with, the curve inferred from imported fertiliser. The effect on yield actually began in 1927 and the maximum effect shown by the smoothed curve through the recorded yields is 1.78 of an ardeb in 1938. The response curve shows that this amount of barley corresponds to about 50 kilos per feddan of nitrogenous fertiliser.

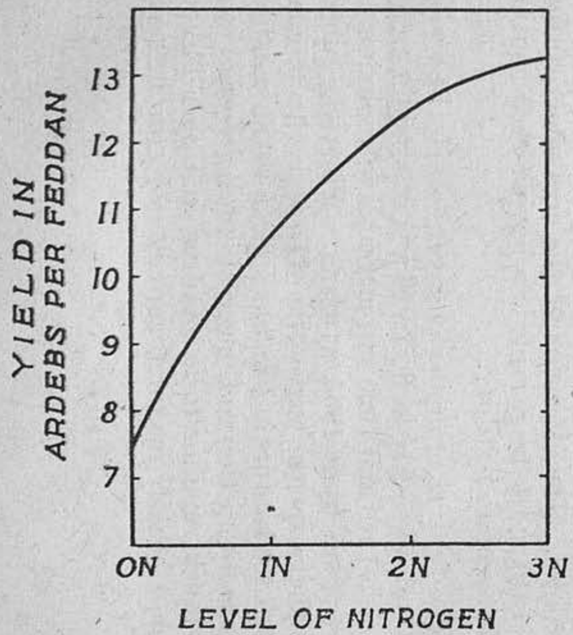
COTTON CROP

In dealing with the nitrogenous fertilisers received by this crop it has been found essential to treat of cotton grown in Upper Egypt separately from that grown in the Delta. Even then it would be wrong to think of either region as homogeneous. The response curves from the cotton manurial experiments in the years 1931-1940 for the two regions as given in figure **17**, show that both the yield without artificial fertiliser, and also the increase obtainable from its use, are higher in Upper than in Lower Egypt. The experiments in the Delta itself, however, can in turn be split up according to latitude into three roughly equal groups. When this is done the lowest average yield without manure, as well as the smallest average benefit from its application, are experienced in the north; both the yield and the benefit increase as one proceeds south. The maximum percentage increase from nitrogen tends to be everywhere constant, but more substantial additions to yield from a given quantity of nitrogen can obviously be expected in the south than in the north since the level of yield increases from north to south.

These differences in the utility of nitrogenous fertilisers for cotton seem to be the result of differences in temperature, especially in the first part of the growing season. The question of temperature and nitrogen uptake is of importance with other crops as well as cotton; it is dealt with below, in a separate section.

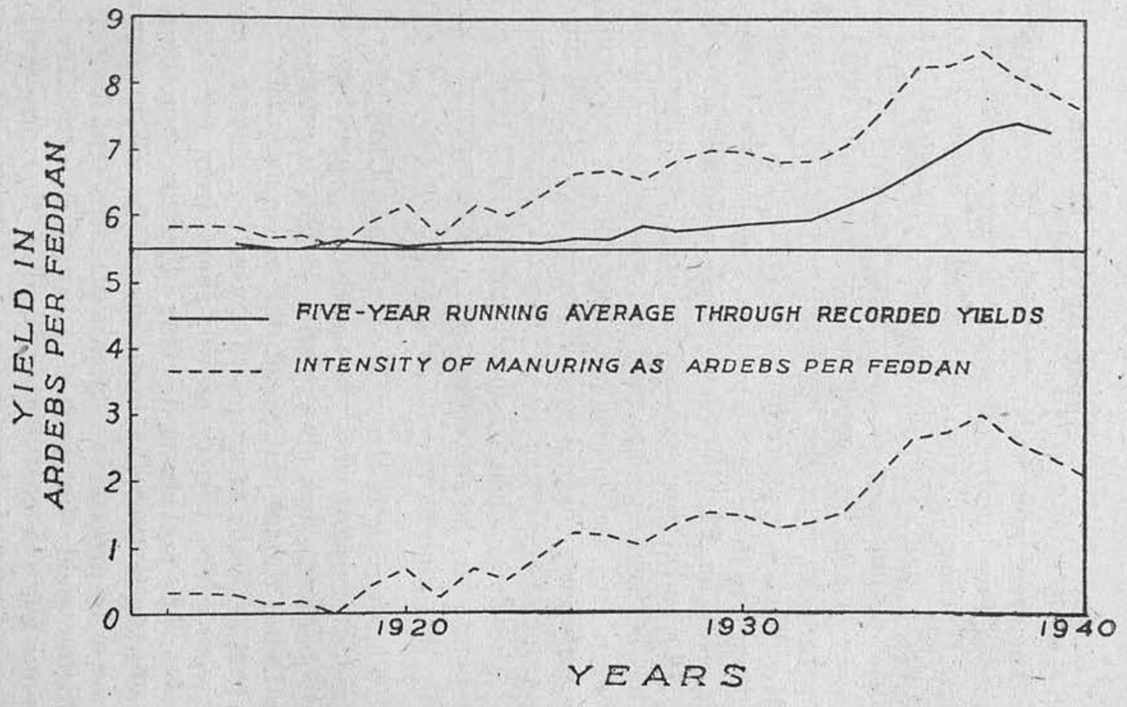
RESPONSE CURVE FROM BARLEY EXPERIMENTS
1935–40
(56 Expts)

FIG. 12 a



BARLEY
1913 – 40

FIG. 12 b



Upper Egypt Cotton

The total area under the crop in Upper Egypt (see fig. **13***b*) exceeded four hundred thousand feddans for the first time in **1920**, thereafter increasing to almost seven hundred thousand in 1930 and rather more than that in 1937. Restriction of the cotton area by law accounts for the very low figures of 1921 and 1932. This increase in area was paralleled by an equally rapid increase in the average yield, from the low level to which it had sunk by 1920 and 1921. With a concurrent increase in the fertiliser imported there are therefore three strong positive associations : between area and average yield (fig. **14***a*) between average yield and intensity of manuring (fig. **14***b*) and between this last and area. Of these the most important is that between average yield and manuring. The partial correlation between area and intensity of manuring is not significant while the one between yield and area is barely so. It will also be noted that the value of the association between yield and intensity of manuring had already reached its maximum by 1933 (see fig. 14b) and that the points for the succeeding seven years when the intensity of manuring was highest add nothing to it.

The increase in the yield of cotton in Upper Egypt is therefore to be ascribed almost wholly to the increased use of nitrogenous fertiliser. Pink bollworm has always affected cotton grown there less than in the Delta, though its spread did, of course, assist the drop in yield to 1921, and the measures to control it played some part in the recovery. The variety grown, apart from the propagation of new strains, has not changed. One objection sometimes raised to this conclusion is that the improvement in yield occurred because the increase in area meant extension of the crop to better land giving a higher yield ; but even if it is assumed that the area added was twenty-five per cent higher yielding than the rest, it would only account for 0.3 of a kantar out of the total increase of over two kantars per feddan. The extension of the area under cotton in Upper Egypt after 1919 must be regarded as having been contingent on a supply of nitrogenous fertiliser.

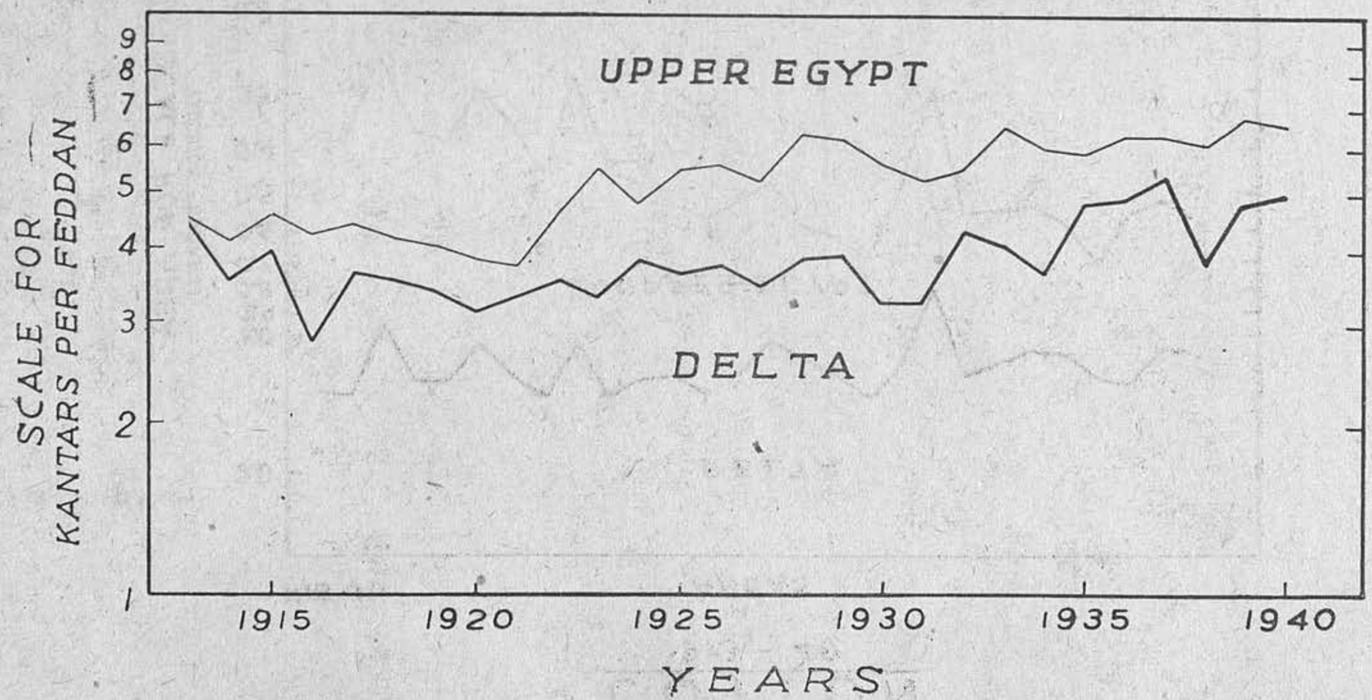
The five-year running average through the recorded yields shown as an unbroken line in figure **16** a is at a minimum of 4.0 kantars per feddan in 1919 and 1920 and increases to a maximum of 6.0 kantars or rather more from 1935 onwards. When the dotted line (derived from the response curve (fig. **17**) and the intensity of manuring) is given 4.0 kantars as the base line for " no manure " it is seen that, in sharp distinction to the cereal crops, recorded experience is always very much superior to it. Cotton in Upper Egypt has been by far the most heavily manured agricultural crop in Egypt and may have

COTTON

1913 - 40

FIG. 13 a

AVERAGE YIELDS

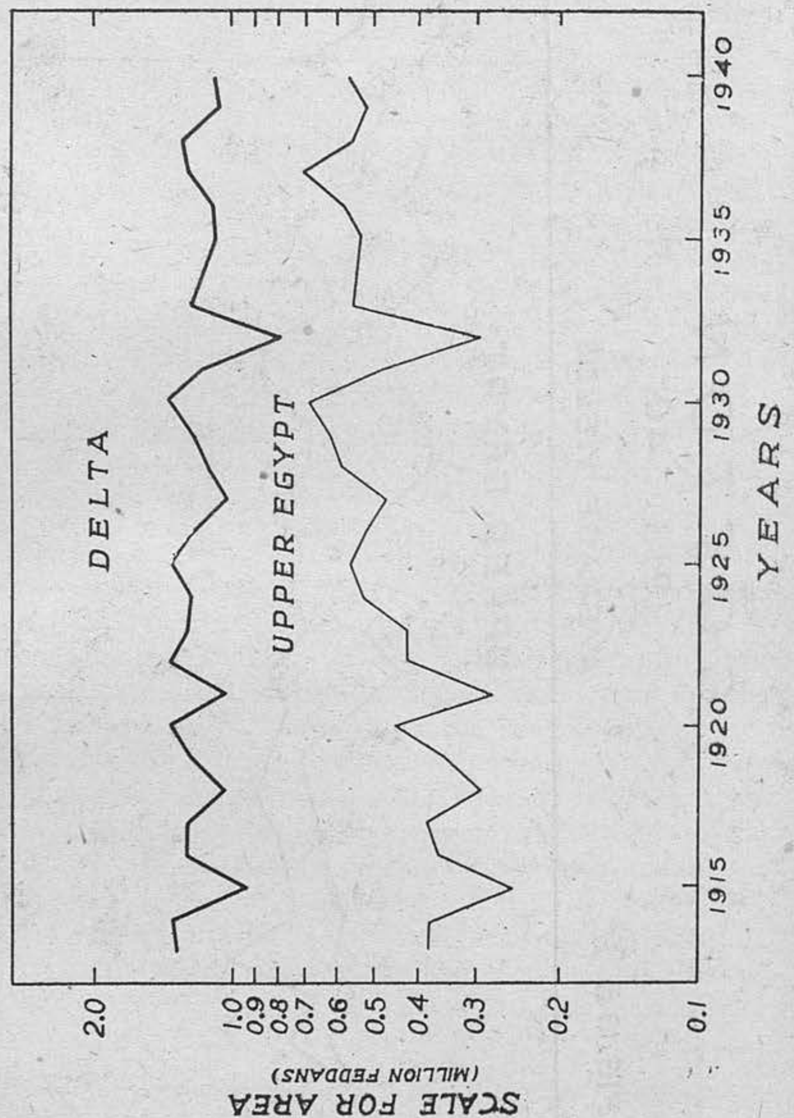


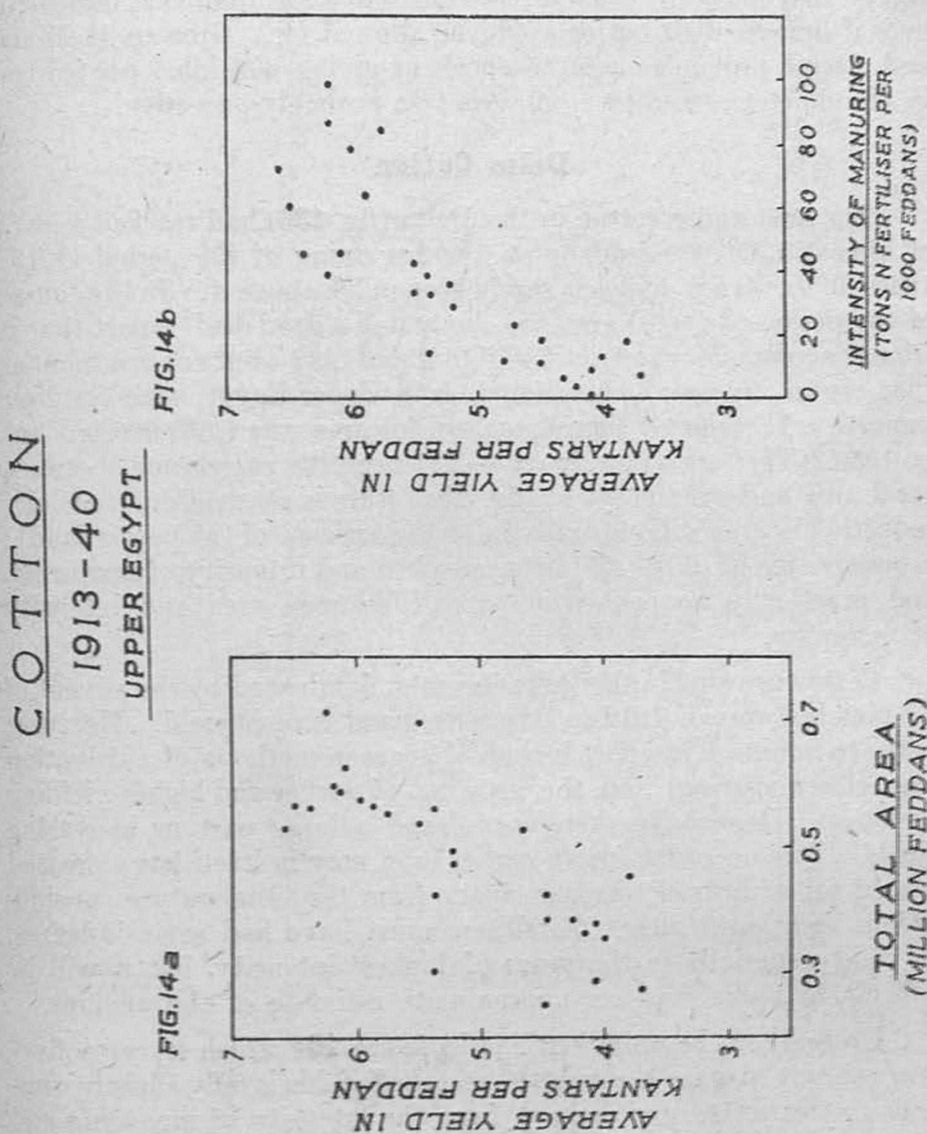
COTTON

1913 - 40

AREAS

FIG. 13b




COTTON
1913-40
UPPER EGYPT
FIG.14a
AVERAGE YIELD IN KANTARS PER FEDDAN
7
6
5
4
3
0.3
0.5
0.7
TOTAL AREA
(MILLION FEDDANS)
FIG.14b
AVERAGE YIELD IN KANTARS PER FEDDAN
7
6
5
4
3
0
20
40
60
80
100
INTENSITY OF MANURING
(TONS N FERTILISER PER
1000 FEDDANS)

been receiving nitrogenous fertiliser at the rate of 3N (46.5 kilos of nitrogen per feddan) even so early as 1928. The high yields recorded in the last five years of the period may have been the result of more efficient utilisation of the fertiliser in consequence of favourable seasons as well as to still greater amounts of it. This influence of temperature is referred to again below. Some cotton areas in Upper Egypt may have received even more fertiliser than that indicated here if uneven distribution could be allowed for. Growers in Minia and Assiut provinces used to speak of giving 600 kilos per feddan in the nineteen-twenties; but this was probably excessive.

Delta Cotton

The area under cotton in the Delta (fig. **13***b*) had reached a level of almost 1,350,000 feddans at the beginning of the period (1913-1940) under review, and has rarely been much above it. In the course of the period the total area has fluctuated a good deal— apart that is from the compulsory restrictions of 1921 and 1932—but not in a manner that can in any way be associated, as in Upper Egypt, with fertiliser imports. The highest figure reached for area was 1,387,000 feddans in 1930. There is a low ($r = -.27$) negative correlation between total area and average yield (fig. **15***a*) (this is reasonable, since any reduction in area will naturally be at the expense of the poorer land): a positive one ($r = +.71$) between yield and intensity of manuring, and practically no connextion at all between area and intensity of manuring.

Cotton growing in the Delta has been dominated by the advent of the pink bollworm in 1912 and the consequent drop in yield. Measures taken to minimise its effect include changes in methods of cultivation (e.g. closer spacing) and the growing of earlier and higher-yielding varieties. These have therefore played a large part in increasing yields. This necessity for an earlier crop may in itself have created a need for additional nitrogen apart from the temperature considerations mentioned later. Fertilisers must have had some influence on yield, especially in the years of highest intensity, but it will be difficult to make even an approximate estimate of the amount.

Up to 1932 the unbroken line in figure **16***b* which traces a five-year running average through the recorded yields is only slightly superior to the dotted one derived from the intensity of manuring and the response curve (fig. **17**) when the latter is given a base line of 3.35 kantars per feddan for "no manure". Thereafter the superiority of recorded experience abruptly becomes very much greater. The contrast offered to the behaviour of the cereal crops (where recorded experience is always less than that inferred), although the contrast is not so extreme as in Upper Egypt, will again be noted.

COTTON

1913-40

DELTA

FIG.15a

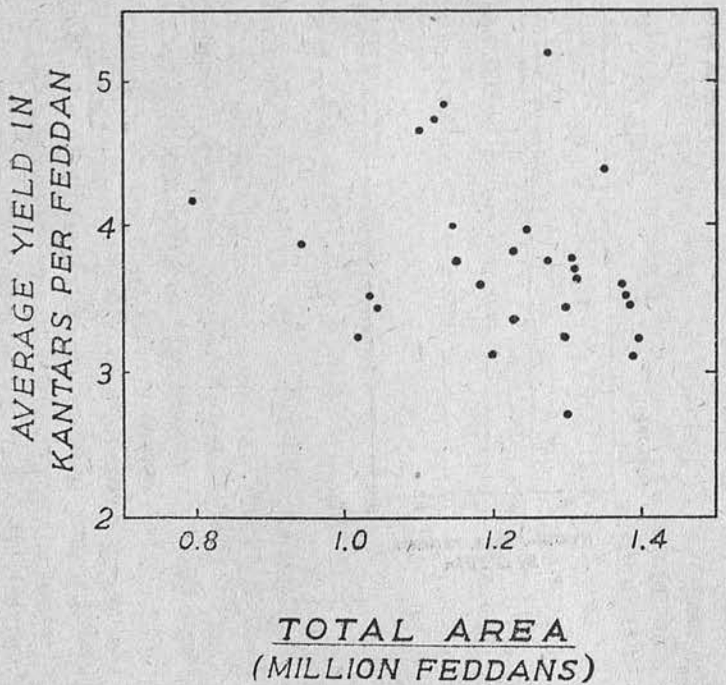
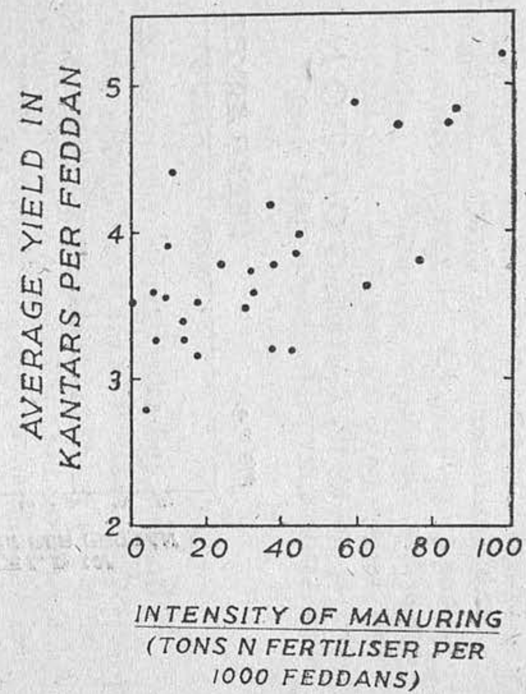


FIG.15b



COTTON
1913 - 40

FIG. 16 a

UPPER EGYPT

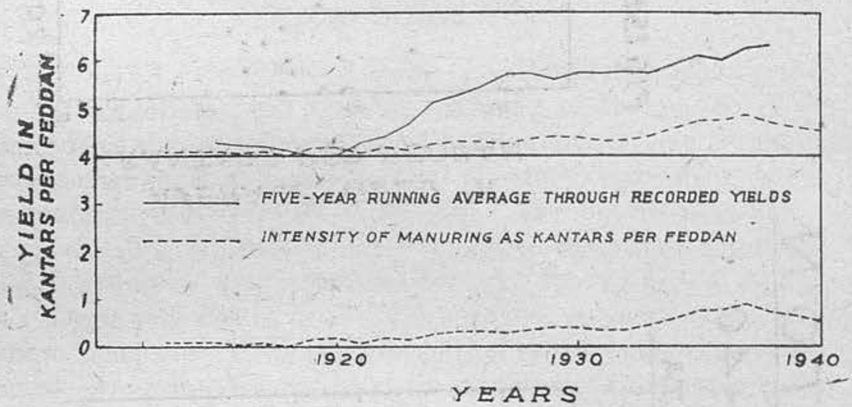
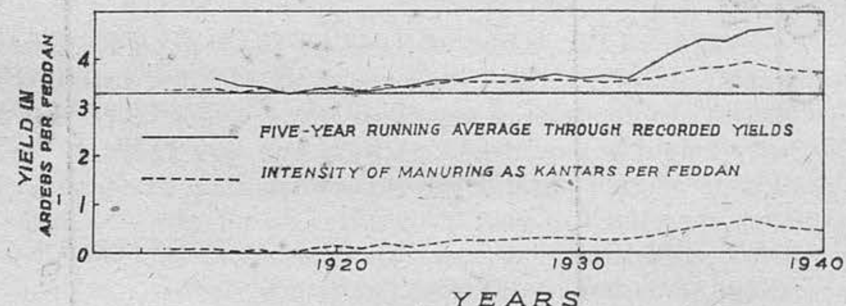


FIG. 16b

DELTA



The increase shown by the smoothed curve for yield up to 1932 over the lowest period in 1918-1921 is roughly about 0.35 of a kantar and thereafter (to 1938) an additional amount of rather more than one kantar, making 1.35 kantars in all. Delta cotton in the period 1935-1940 was receiving at least 100 kilos of the fertiliser per feddan, equivalent on the response curve to 0.70 of a kantar, and was probably getting more if uneven distribution is allowed for since the use of artificial nitrogen would spread gradually from the south northwards ; low-yielding cotton in the north is very unlikely ever to have received any fertiliser at all.

SUGAR CANE

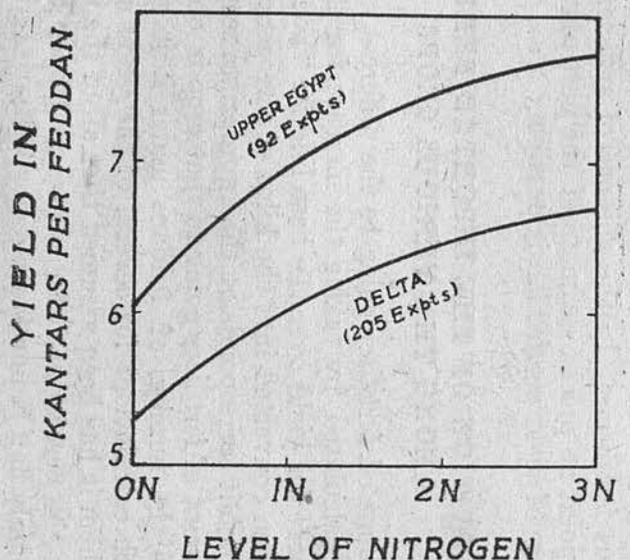
In figure **18** the total area under cane in Upper Egypt has been set against the tons crude sugar produced at the factories for the years 1900-1940. If the years 1900-1905 (the period of change to the variety called P.O.J. 105) are excluded, there is a close correspondence between area and suger production, which shows that even if production of factory sugar were to stop entirely, there would still be a very considerable area under cane in Upper Egypt. If a constant 29,000 feddans is subtracted from the total area in each year there is such a close association between the adjusted area and the tons sugar produced (fig. **19**) that the area involved must be considered as the principal factor determining the quantity of sugar available. A five-year running average through the tons of sugar produced per feddan of this adjusted area shows it to have a minimum of 2.90 tons in 1919 and 1920 and a maximum of almost 4.90 tons in 1934, 1935 and 1936 ; this increase is evidently associated with increased importation of nitrogenous fertilisers. In the absence of sufficient experimental data on the point no precise estimate of the part played by nitrogen in the increase of yield per feddan is possible.

REPARTITION OF THE IMPORTED FERTILISER AMONG THE VARIOUS CROPS

The amount of fertiliser going to the different crops in any one year can be calculated by taking the increase for that year on the smoothed curve for yield over the base line for " no manure ". This increase is then converted into the kilos of nitrogenous fertiliser per feddan to which it corresponds on the appropriate response curve and the total amount of fertiliser going to that crop is obtained by multiplying into the number of feddans under it in that year. The result of such calculations for several of the years are given below. In making them it has been assumed that all of the increase in yield recorded for the cereals and for cotton in Upper Egypt is due to nitrogen but only half (a purely arbitrary half) of the increased cotton

RESPONSE CURVES FROM COTTON EXPERIMENTS 1931 – 40

FIG. 17



SUGAR CANE 1900 – 40

FIG. 18

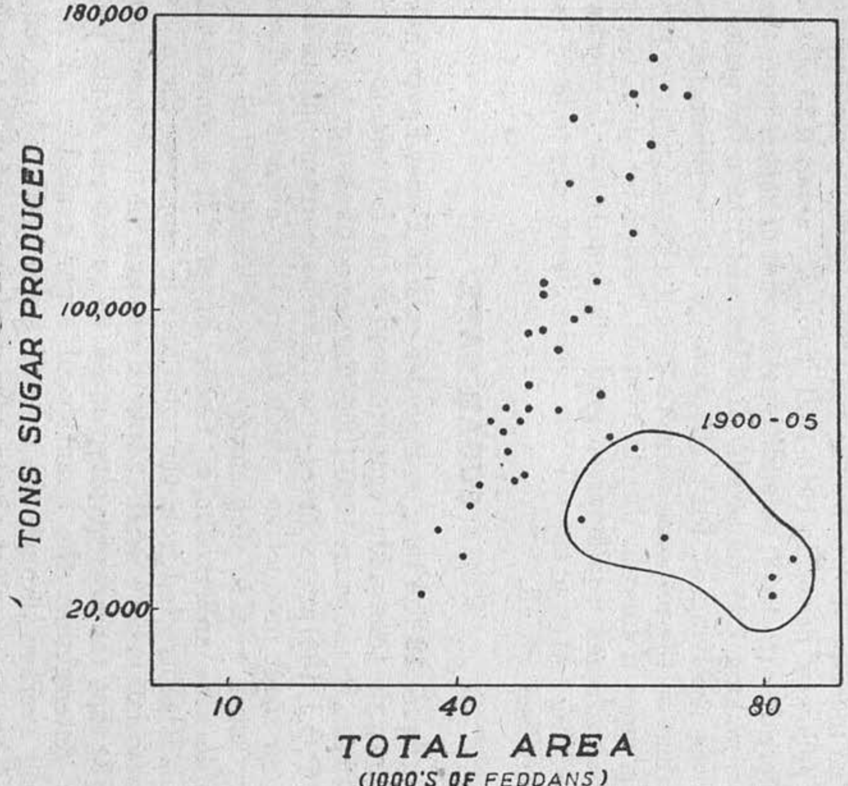
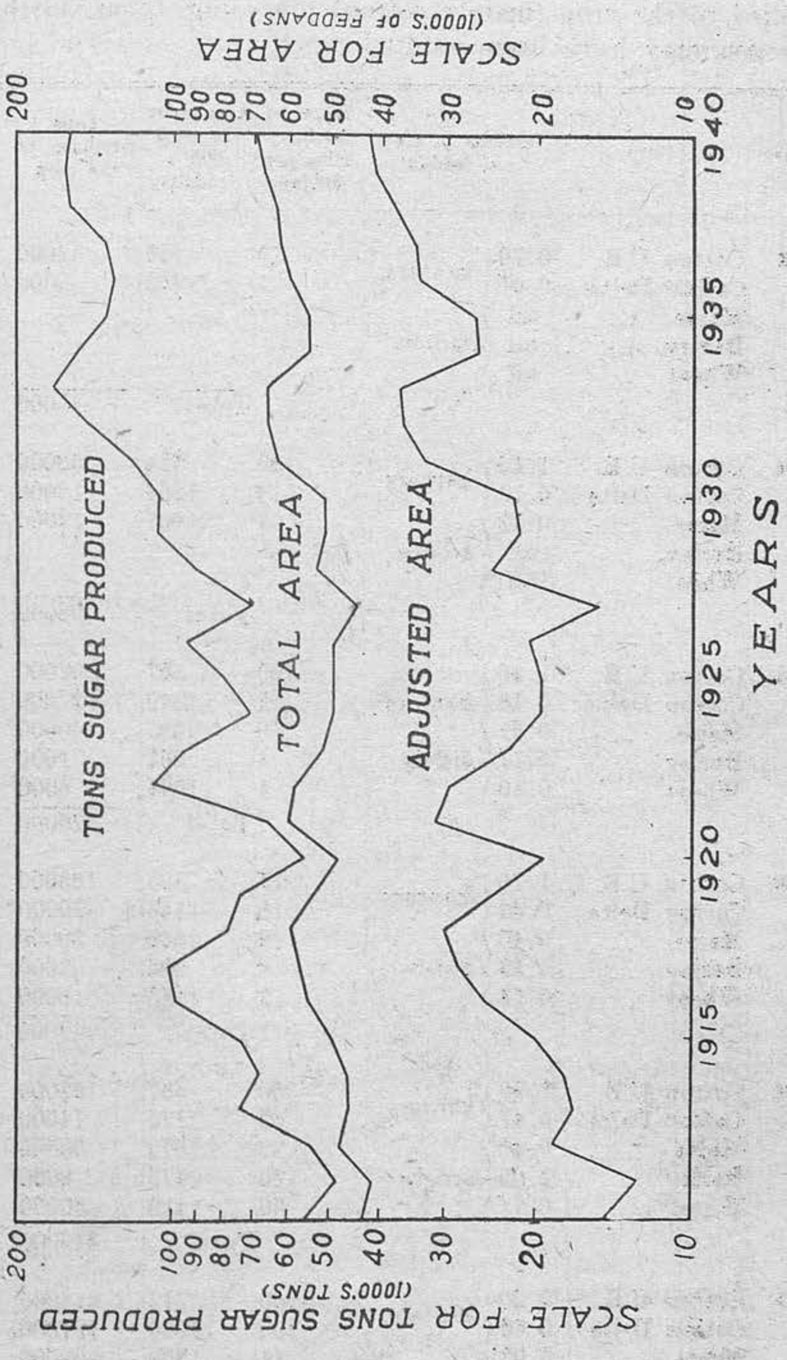


FIG.19

SUGAR CANE

1910 - 40



yield in the Delta is so regarded. The tons fertiliser shown as going to the wheat and barley crops include the residual effects of nitrogen applied to the crop (mainly cotton) preceding them, so that some nitrogen may have been counted twice.

Year	Crop	Increase in yield per feddan		Equal to fertiliser kilos per feddan	Area under the crop (000's feddans)	Tons fertiliser to the crop	Tons fertiliser imported
1923...	Cotton U.E. ...	0.70	kantars	75	426	32000	
	Cotton Delta	0.07	kantars	7	1289	9000	
	Maize	nil	ardebs	—	—	—	
	Barley	nil	ardebs	—	—	—	
	Wheat	nil	ardebs	—	—	—	
					Total ...	41000	**79171**
1924...	Cotton U.E. ...	1.10	kantars	130	524	68000	
	Cotton Delta	0.12	kantars	14	1264	18000	
	Maize	0.22	ardebs	7	1807	12000	
	Barley	nil	ardebs	—	—	—	
	Wheat	nil	ardebs	—	—	—	
					Total ...	98000	**134746**
1926...	Cotton U.E. ...	1.40	kantars	190	537	102000	
	Cotton Delta	0.18	kantars	22	1249	27000	
	Maize	0.42	ardebs	19	2085	40000	
	Barley	0.17	ardebs	4	361	1000	
	Wheat	0.10	ardebs	4	1594	6000	
					Total ...	176000	**202817**
1928...	Cotton U.E. ...	1.70	kantars	275	595	163000	
	Cotton Delta	0.44	kantars	18	1143	20000	
	Maize	0.40	ardebs	19	2053	39000	
	Barley	0.22	ardebs	6	386	2000	
	Wheat	0.24	ardebs	12	1555	18000	
					Total ...	242000	**238000**
1934...	Cotton U.E. ...	1.90	kantars	+300	557	167000	
	Cotton Delta	0.47	kantars	63	1175	74000	
	Maize	0.68	ardebs	32	1572	50000	
	Barley	1.09	ardebs	30	279	8000	
	Wheat	0.77	ardebs	36	1410	50000	
					Total ...	349000	**353748**
1937...	Cotton U.E. ...	2.20	kantars	+300	712	214000	
	Cotton Delta	0.66	kantars	100	1266	127000	
	Maize	0.93	ardebs	44	1559	69000	
	Barley	1.78	ardebs	50	264	13000	
	Wheat	1.24	ardebs	60	1417	85000	
					Total ...	508000	**560362**

The discrepancy between the amounts actually imported and those calculated as going to the various crops is quite large up to 1927. But distribution of fertiliser in the cotton areas was never uniform, and in the nature of things it would at first be distorted compared with what it afterwards became ; much more must therefore have been going to these areas than is shown. It has already been mentioned that in the nineteen-twenties there were enthusiastic growers in Minia and Assiut provinces who thought it desirable to give as much as six hundred kilos or more of fertiliser per feddan. Such very uneven distribution would also account for the delayed appearance of residual effects from imported nitrogen on wheat yields, whereof there is no sign until the 1927 harvest (1926 fertiliser year). The discrepancy in the later years (e.g. 1937) in the amounts going to the chief agricultural crops and the amount imported is accounted for by uneven distribution and by sugar cane, by orchards (bananas are very heavily manured), and by market garden crops generally. Cotton has always been the most heavily manured crop ; in the early 1920's it was receiving practically all the fertiliser imported ; even in 1937, the year of largest importation, it did not get less than 340,000 tons out of a total of 566,000 tons and it may have received considerably more.

EFFECT OF SEASONAL VARIATIONS

All of the above must now be qualified by a consideration of the temperatures recorded before and during the period reviewed.

The greater response to nitrogen of cotton in Upper Egypt compared with Lower Egypt or in the southern Delta compared with the northern Delta has been shown, from the analysis of variation in cotton experiments[1], to be an expression of the higher temperatures experienced, particularly in the earlier part of the growing season. It is equally important to realise the implications of long-term alterations in climate, similar to the geographic alterations encountered in moving between north and south in the cotton-growing area. Such a long period change to higher temperature occurred during the thirty-five years from 1904 to 1940, thus including the period which has been reviewed.

In figures **20** and **21** are shown the five-year running averages through the monthly mean of day (true mean) temperatures at Helwan

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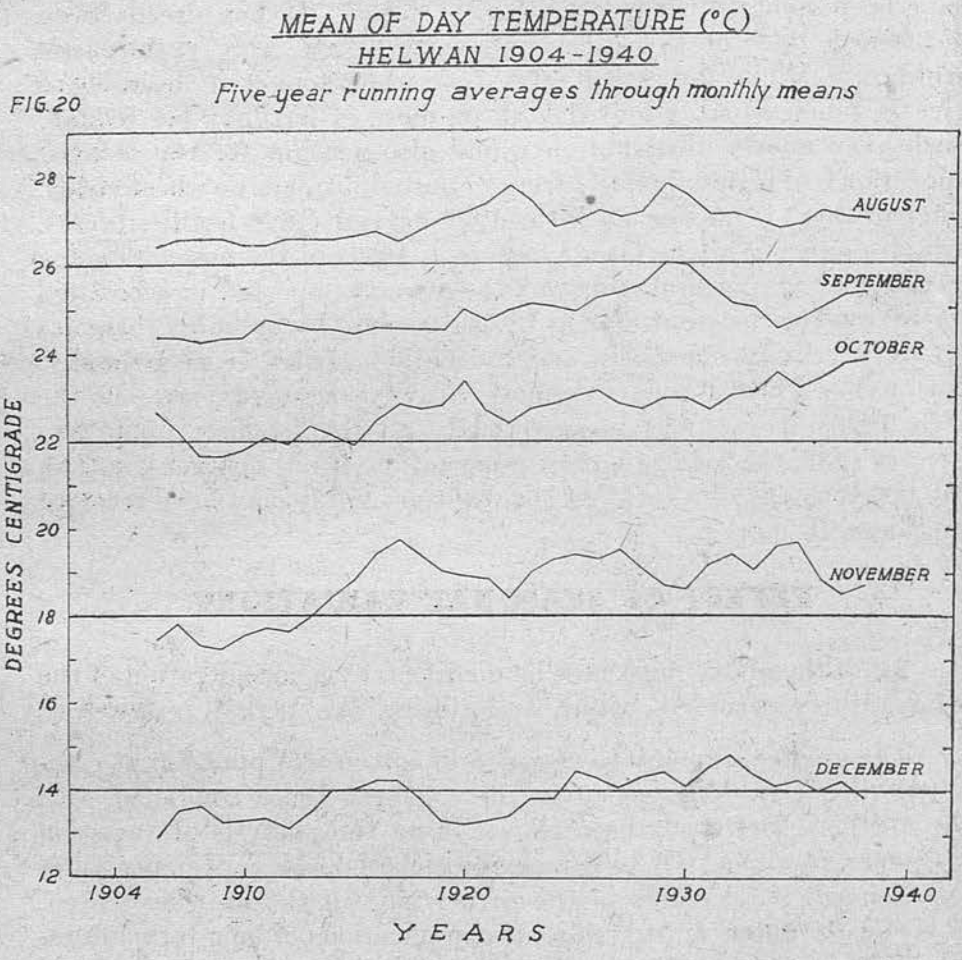
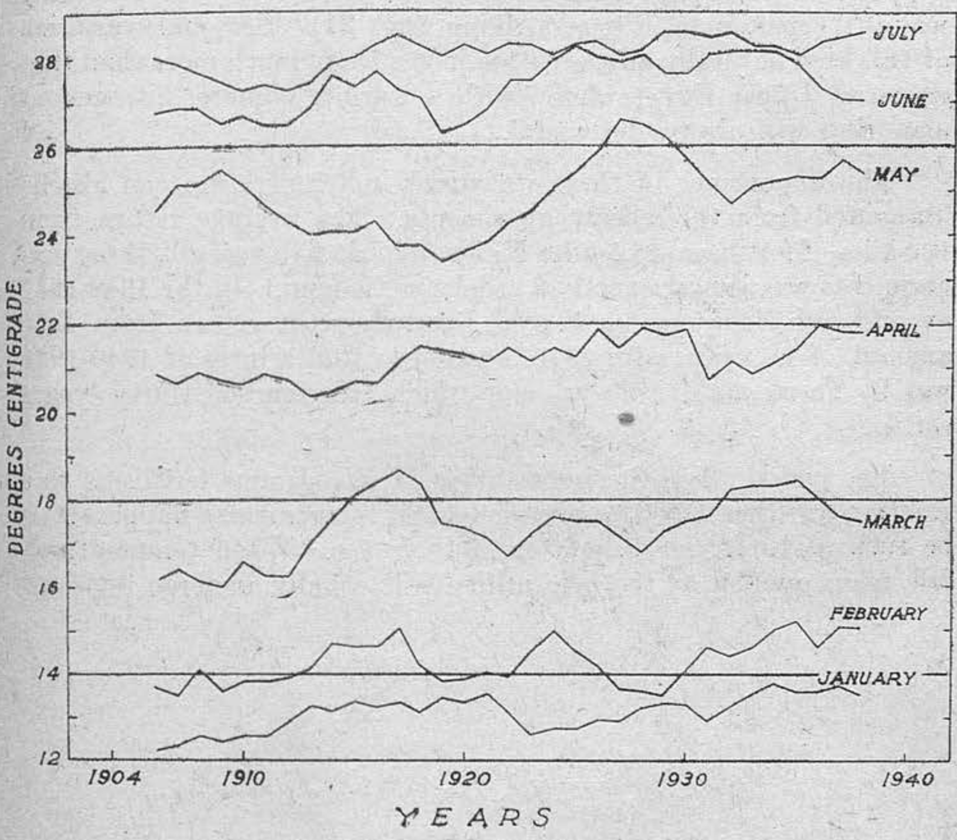
(1) " Les effets du sol, de la saison et de la fumure sur la vegetation et le rendement du cotonnier". Bull. de l'Union des Agriculteurs d'Egypte, Mars 1939. No. 301. (D.S.G.)

David S. Gracie, " The organic content of soils of the Middle East" Procee the Conference on Middle East Agricultural Development. p. 107. (1944).


MEAN OF DAY TEMPERATURE (°C)
HELWAN 1904-1940
Five-year running averages through monthly means
FIG. 20
DEGREES CENTIGRADE
28
26
24
22
20
18
16
14
12
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
1904
1910
1920
1930
1940
YEARS

MEAN OF DAY TEMPERATURE (°C)
HELWAN 1904-1940
Five year running averages through monthly means

FIG. 21



Observatory for the years 1904-1940. These show that the period of rapid increase in nitrogenous fertiliser imported was also on the whole a period of high or rising temperature. Prior to 1914 the opinion was expressed that the nitrogenous manuring of cotton in the Delta did not pay (1) which was certainly not the case in the seven years prior to 1940(2) The difference between the low temperatures in March which were normal when that opinion was formed, and those which happened regularly in 1933-1940 when the intensity of manuring was at its maximum, is very striking (fig. **21**). Seasonal variation of this kind naturally affects cotton in the Delta much more than that grown in Upper Egypt where, with a warmer climate, nitrogenous manuring will always be useful.

The importance of these variations in temperature can also be illustrated from the wheat experiments. The average return from 100 kilos of fertiliser (15.5 kilos N) for the first five years of these experiments was almost exactly 2 ardebs per feddan. In the 1940-1941 experiments, following on a cold December, the return from that amount of nitrogen sank to 1.23 ardebs; that winter of 1940-1941 was by no means so cold as some which are recorded thirty years earlier.

The period when the importation of nitrogenous fertilisers was greatest was therefore also a period when temperatures happened to be such as to favour benefit from their use. When temperatures fall again opinion as to their utility will equally undergo revision.

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(1) F. Hughes, Year-Book of the Khedivial Agricultural Society, 1909, p. 159.
J.A. Prescott, Bulletin No. 13 of the Sultanic Agricultural Society, 1924, p. 47.

(2) See references on p. 31.

SUMMARY

Agronomic experimental data on nitrogenous manuring for 1931-1940 have been used to interpret statistical information.

The extra weight of crop produced during 1913 to 1940 has been taken as a measure of the weight of nitrogenous fertiliser which each crop obtained.

Due allowance is made for non-manurial factors, often revealed by the methods employed.

The secular temperature change of climate during the thirty-five years from 1904 is one such factor.

Fully half the nitrogen imported by Egypt is applied to cotton in Upper Egypt. Much less goes to Delta cotton and still less to the wheat crop. Maize gets less per feddan than wheat or barley.

The inquiry began in answer to questions about the most efficient use of scanty shipping-space to provide cereal food for Egypt during the war years.

والشكل رقم ١١ يظهر مقدار الوارد من الأسمــدة الأزوتية من سنة ١٩١١ الى سنة ١٩٤٠ وقد أفترض أن المقدار الوارد فى أى عام يصرف لمحاصيل القطن والذرة الشامية والذرة الرفيعة والأرز والقمح والشعير فى نفس "العام السمادى" ليعطى رقما بالطن للألف فدان (أو بالكيلوجرامات للفدان الواحد) وقد سمى هذا الرقم "كثافة التسميد الأزوتى" (الشكل رقم ١ ب)، و رسم هذان الشكلان وكذلك الأشكال رقم ٢ — ٥ و١٣ و١٣ب و١٩ الدالة على المساحات ومتوسط غلات المحاصيل المختلفة على أوراق مقسمة تقسيما لوغارتميا لتعطى فكرة عن مدى الزيادة أو النقص حيث إن المسافات الرأسية المتساوية على المقياس اللوغارتمى تدل على فروق مئوية متساوية، وبذلك أمكن ترجمة الشكل الدال على مقادير الأسمدة بالطن للألف فدان الى قناطير أو أرادب للفدان، وذلك بالاستعانة بمتوسطات نتائج تجارب التسميد التى أجريت بين سنتى ١٩٣١ و١٩٤٠ وقــد بلغت "كثافة التسميد" أقصاها فى سنة ١٩٣٧ حيث كانت بمعدل ٩٧ طنا للألف فدان، وكان أدناها فى سنة ١٩١٨ حيث هبطت الى صفر

خلاصــة

استعملت نتائج تجارب التسميد الأزوتى فى السنين (١٩٣١ — ١٩٤٠) فى ترجمة المعلومات الإحصائية.

اعتبرت الزيادة فى المحصول بين سنة ١٩١٣ و سنة ١٩٤٠ مقياساً لمقدار السماد الذى خص كل محصول على حدة.

عمل حساب للعوامل غير السمادية ومنها التغير فى درجات الحرارة فى مدى خمسة وثلاثين عاما منذ سنة ١٩٠٤

نصف الأزوت الذى تستورده مصر يستعمل فى تسميد القطن بالوجه القبلى وأقل من ذلك بكثير مايسمد به القطن فى الوجه البحرى، ويقل عن ذلك الأخير مايعطى لمحصول القمح. أما محصول الذرة فيناله أقل مما ينال القمح أو الشعير.

وقد بدئ هــذا البحث للإجابة عن أفضل وسيلة للانتفاع بالحيز الضيق فى الشحن المـائى لمساعدة مصر على إنتاج حبوبها فى سنى الحرب.

تقدير أثر الأسمدة الأزوتية
بالجمع بين البيانات الإحصائية والزراعية

تأليف

و. لورانس بولز ، دكتوراه فى العلوم وعضو الجمعية الملكية.

و

ديفد . س . جريسى ، بكالوريوس فى العلوم وزميل بالمعهد الكيميائى الملكى.

و

فهمى خليل ، بكالوريوس فى العلوم ودكتوراه فى الفلسفة.

مقـدمة

كان النقص الهائل الذى طرأ على النقل البحرى أثناء سنى الحروب (١٩٣٩ — ١٩٤٦) باعثا على جمع المعلومات الدالة على مدى اعتماد مصر فى إنتاج غذائها على الأسمـدة الصناعية التى أخذت المقادير الواردة منها تزداد أثناء العشرين عاما السابقة فى حين أنهـا لم تكن لتعرف تقريبا عند بداية هذا القرن .

ويوجد مصدران للمعلومات كل منهما مفيدعلى حدته، غير أن الفائدة تتضاعف كثيرا بالجمع بينهما . مثال ذلك ما هو معروف من نتائج قسم التجارب الزراعية من أن عشر طن من النترات يزيد محصول الفدان فى المتوسط بمعـدل أ كثرمن ربع طن (١,٨ إردب) من القمح، وهذا القدر يشغل بطبيعة الحال حيزا فى بواخر النقل أكبر من الحيز الذى يشغله مقدار النترات الذى نشأت عنه هذه الزيادة فى محصول القمح . وبناء على ذلك كان من الواضح — اقتصادا فى وسائل النقل البحرى — أن يؤتى بالسماد النتراتى لمصر لإعانتها على انتاج غذائها بنفسها بدلا من أن يؤتى لهـا بالقمح — غير أن السؤال التالى وهو : " ما مقدار الجزء الذى يعطى عادة من النترات المستوردة لمحصول القمح والمحاصيل الغذائية الاخرى ؟ " بقى دون جواب فكتاب الإحصاء السنوى لا يقدم هذه المعلومات بطريقة مباشرة، ولكن بالاستعانة بأرقامه و بالحقائق الزراعية معـا أمكن الوصول لذلك وللكثير من المعلومات الأخرى المرغوب فيها ، وبهذه النشرة ملخص لتلك الحقائق التى أمكن التوصل اليها .

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service

CHEMICAL SECTION

Bulletin No. 251

The Total and Available Phosphoric Acid in Egyptian Soils and the Effect of Superphosphate on the Main Agricultural Crops

BY

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GOVERNMENT PRESS, CAIRO, 1948

Government Publications are on sale at the " Sale Room ", Ministry of Finances. Correspondence relating to these publications should be addressed to the " Publications Office," Government Press, Bûlâq, Cairo.

Price - - - - - - P.T. 22

CONTENTS

TOTAL AND AVAILABLE PHOSPHORIC ACID

GENERAL AND INTRODUCTORY

The unbalanced nature of the consumption of artificial fertilisers in Egypt as compared with other agricultural countries has frequently been commented on in the past. Thus the use of potash fertilisers, except for small amounts of potassium nitrate, has been practically unknown, while the consumption of superphosphate has always been small compared with that of nitrogen. The importation of superphosphate increased slowly from 1920 onwards to reach the figure of 86,000 tons in 1936, while nitrogenous fertilisers imported rose to a maximum of over half a million tons during the same period.

The reasons for this state of seeming unbalance between nitrogen and phosphorus are to be found in the fact that the Nile alluvium and therefore the basin land soils built up from it are well supplied with phosphoric acid. Conversion of these basin land soils to perennial irigation, with its more intensive system of agriculture, is still comparatively recent so that there has not been time for exhaustion to become extreme, although it is proceeding. Moreover, the system of agriculture practised under perrenial irrigation is conservative in that it ensures the return to the soil of considerable amounts of the phosphoric acid removed in crops.

This bulletin is concerned with tracing the course of this gradual removal and redistribution of phosphoric acid in perennially irrigated soils and, as a corollary, with the response to superphosphate (in field experiments) of the main agricultural crops grown on them. It includes, therefore, the part dealing with pnosphoric acid of the general study which is being made of the properties of perennial as compared with basin land soils.

For the purpose of that study land still under the basin system, land that has never been under summer cultivation, is being taken as representing the original (average) condition of land now under the perennial system. The assumption is made (it will be seen below to be approximately correct for phopsnoric acid) that, as laid down, the composition and properties of all layers of basin land soils are the same so that variation with depth is non-existent or small. Any departure from this condition in perennial land will therefore represent changes due to the alteration of the system of irrigation and cropping. The basin land profiles studied are mainly from Assiut, Girga and Qena Provinces but include four from Minia, Beni Suef and Giza. The perennially irrigated soils are almost invariably from the series of profiles taken in connection with manurial experiments. The letter are well distributed throughout the country but it should be remembered that their sites are chosen with bias towards the good. Twenty-three profiles of perennial land have been examined for both total and available phosphoric acid. They include four each from the Provinces of Gharbia and Menufia, one from Behera, two from Daqahlis, three each from the Provinces of Sharqia and Qaliubia, and in Upper Egypt, one from Giza, two each from the Provinces of Beni Suef and Minia and one from Assiut. Enough samples have been examined to enable the discussion of the results to take place on a statistical basis.

Total Phosphoric Acid

The average total phosphoric acid content (1) of nineteen profiles from basin land is compared in Table I with the average for twenty-three from perennial land.

TABLE I

TOTAL PHOSPHORIC ACID PER CENT

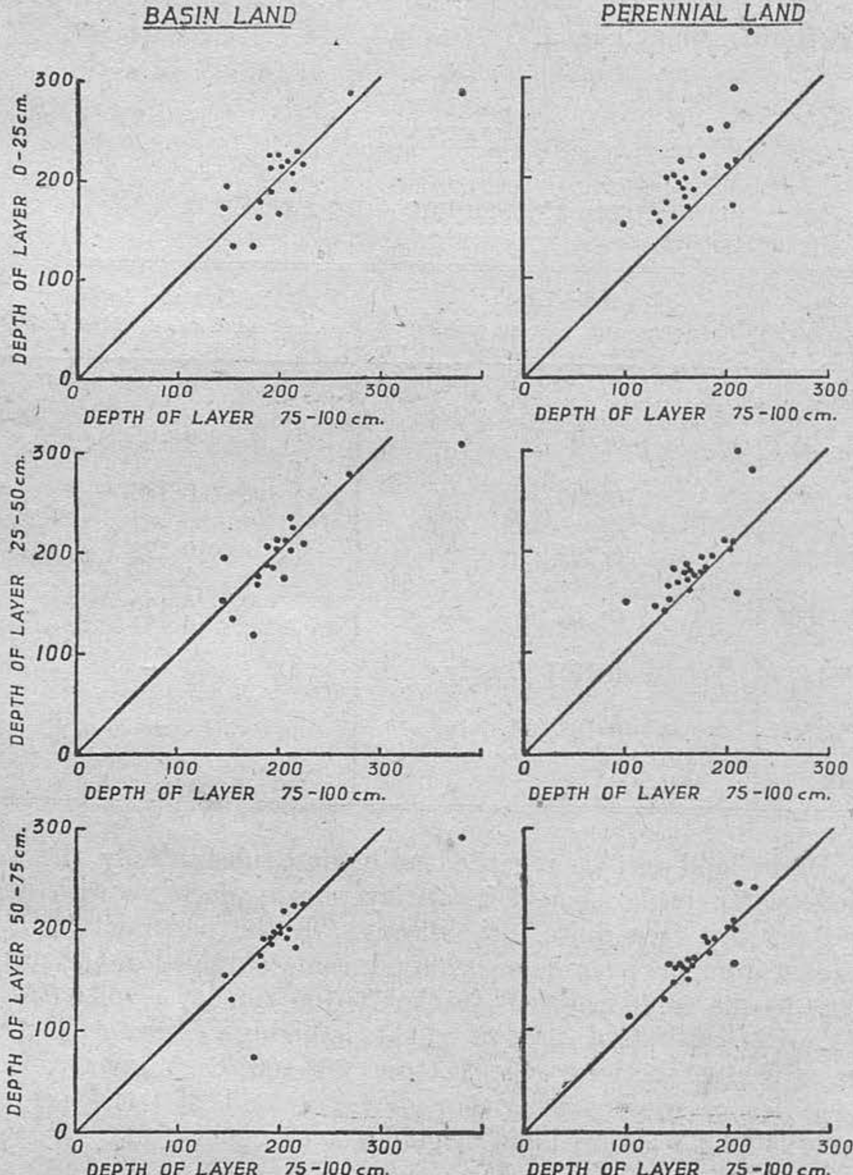
Depth of Layer	Basin Land (Average of nineteen profiles)	Perennial Land (Average of twenty-three profiles)
cm.		
0– 25	0·201	0·206
25– 50	0·200	0·186
50– 75	0·191	0·173
75–100	0·204	0·170
100–125	(0·191) 17 only	—
125–150	(0·183) 14 only	—

Basin land can be regarded as having substantially the same amount of phosphoric acid in all layers, any decrease with depth being in any case quite insignificant. In the perennial land the decrease from the average of 0·206 per cent contained in the surface layers to the 0·170 per cent in the 75–100 cm. layers of 0·036 per cent, with a standard error of 0·0114, is highly significant ($P < \cdot 01$). The difference between the bottom (75–100 cm.) layers of the two series of profiles in favour of basin land of 0·034 per cent $\pm 0 \cdot 0128$ (S.E.) is also highly significant (P again $< \cdot 01$).

(1) For the methods of analysis used and the results of individual profiles, see Appendix,

TOTAL PHOSPHORIC ACID
(MILLIGRAMS PER CENT)

FIG. 1



The diagonal lines are lines of equality

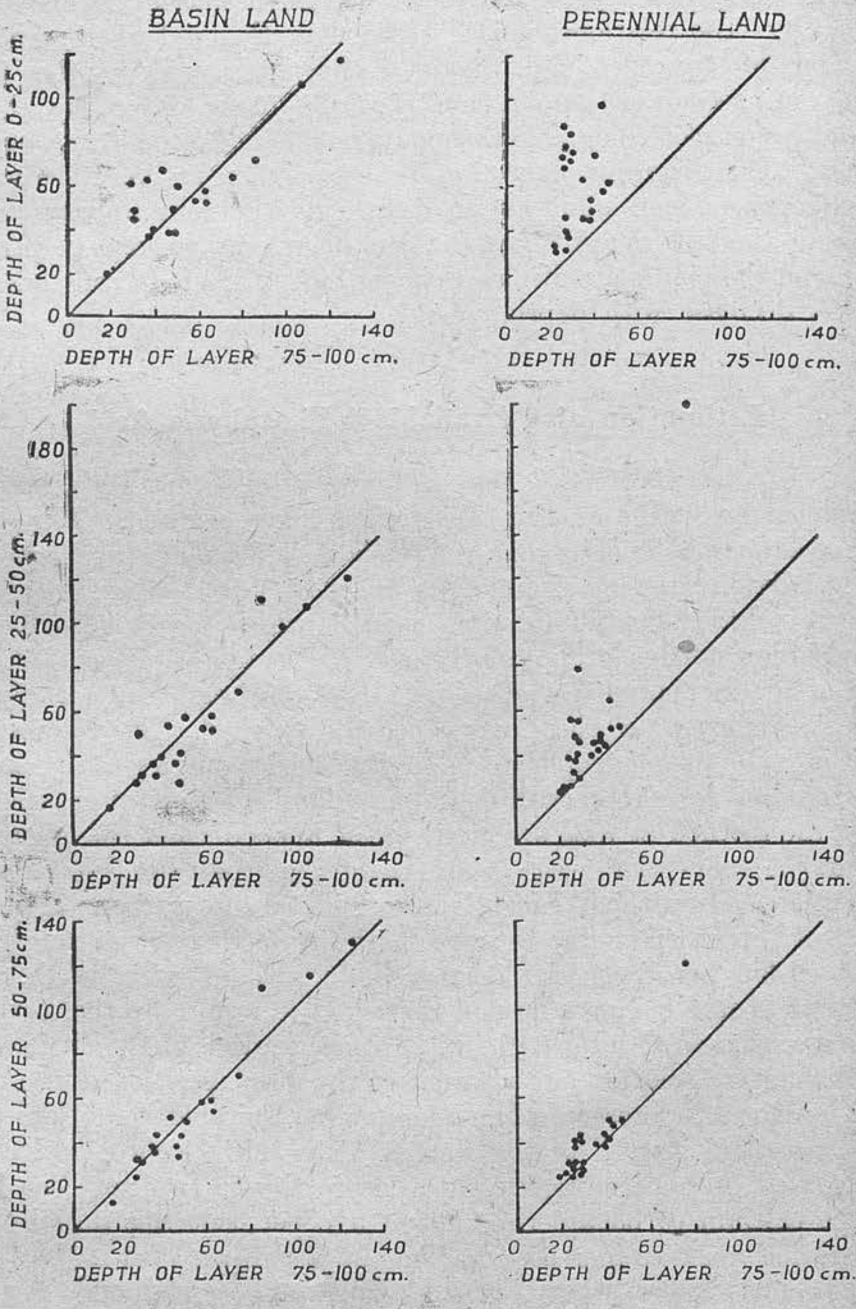
In both series the phosphoric acid content is a characteristic feature of any given profile so that the amount present in one layer is more or less closely related to that found in the layers above or below it. The relationship is illustrated in Figure 1 where, separately for two types of land, the total phosphoric acid in the first (0-25 cm.) second (25–50 cm.) and third (50–75 cm.) layers have been in succession plotted against that contained in the bottom (75–100 cm.) layers. The diagrams show that the association is closest between neighbouring layers and that in basin land the points always tend to group themselves well about the lines of equality whereas in perennial land the points are displaced to one side of them, in consequence of the decrease with depth.

Estimation of "Available" Phosphoric Acid

The total phosphoric acid in these profiles has been further examined by means of the Aspergillus niger method. This biochemical method for determining "available" phosphoric acid consists essentially in growing the fungus under standard conditions in a culture solution containing citric acid in which the only source of phosphorus is five grams of the soil under investigation. At the end of the incubation period of four days the tough mat of mycelium is removed, washed, oven-dried and weighed. The determination is made in quadruplicate in conical flasks offering a constant surface area for the growth of the mycelium. Details of experience with the method at Giza are given in the appendix but the following points in connection with it are useful to the discussion here. Egyptian soils without exception contain calcium carbonate, generally of the order on the average in the surface layers of perennial land of 3·0 per cent, and decreasing in amount with depth. In order to ensure comparable and reproducible results by the method it is essential so to adjust the initial concentration of the citric acid in the culture solution as to permit of the decomposition of the calcium carbonate present while maintaining suitable conditions for the successful growth of the fungus. The initial concentration of citric acid ordinarily employed to ensure this is two per cent but if the calcium carbonate rises above five per cent this initial concentration must be increased to two and a half per cent if the final pH value is to be below 3·0 and reliable and reproducible results are to continue to be obtained. The further addition of citric acid beyond that necessary to fulfil these conditions will occasion further small increases in the weights of mycelium obtained. While, therefore, the Aspergillus niger method is regarded as affording a satisfactory and convenient means of separating the total phosphoric

FIG. 2

AVAILABLE PHOSPHORIC ACID
(MILLIGRAMS PER CENT)



The diagonal lines are lines of equality

acid into the two categories of "available" and "residual", there is no very sharp distinction between the two forms.

The relationship between the phosphoric acid taken up and the weight of mycelium produced has been determined by analysis of the dried mycelium over the range of weights encountered. The graph showing this relationship is given in the appendix. It is not a straight line since the percentage of phosphoric acid in the mycelium is not constant but increases from 0·26 to 0·72 as the quantity of available phosphorus increases. By means of this graph the weights of mycelium obtained from the soil samples from the layers of the profiles from basin and perennial land have been converted to terms of milligrams "available" phosphoric acid per 100g. of the soils. For comparison with the results of the field experiments it is convenient to employ the weights of mycelium (per 20g. of soil) as such.

"Available" and "Residual" Phosphoric Acid

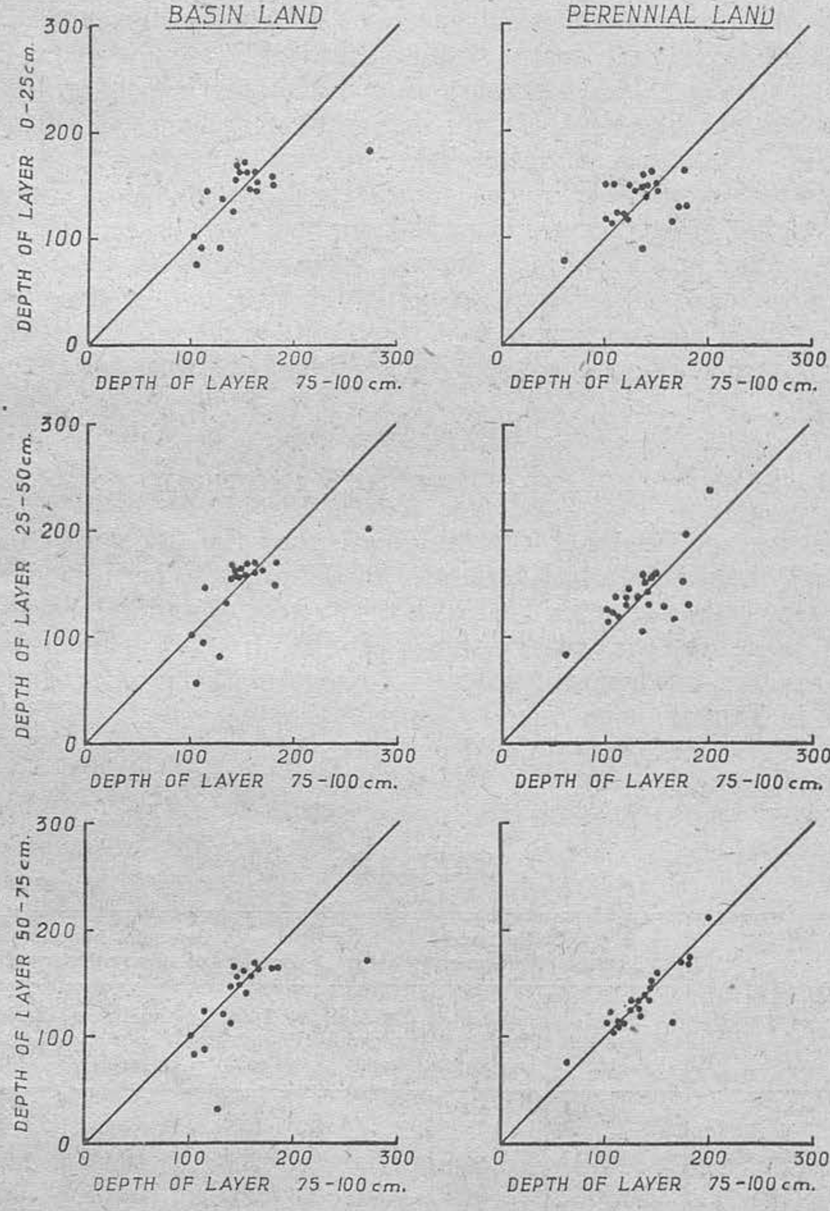
The average results of the examination by the Aspergillus niger method of the total phosphoric acid in the nineteen basin land profiles are compared in Table II with the average of similar determinations made on the twenty-three profiles from perennial land. The average total phosphoric acid content of the profiles, already given in Table I, is included to assist in the comparison. All figures are milligrams phosphoric acid per 100g. soil.

TABLE II

Depth of Layer	Basin Land (Average of nineteen profiles)			Perennial Land (Average of twenty-three profiles)		
	Total Phosphoric acid	Available Phosphoric acid	Residual Phosphoric acid	Total Phosphoric acid	Available Phosphoric acid	Residual Phosphoric acid
cm.						
0– 25 ...	201	58	143	206	66	140
25– 50 ...	200	54	146	186	50	136
50– 75 ...	191	55	136	173	38	135
75–100 ...	204	54	150	170	34	136
100–125 ...	(191) 17 only	(52)	(139)	—	—	—
125–150 ...	(183) 14 only	(50)	(133)	—	—	—

FIG.3

RESIDUAL PHOSPHORIC ACID
(MILLIGRAMS PER CENT)



The diagonal lines are lines of equality

As with total phosphoric acid the amounts of "available" and "residual" phosphoric acid in basin land can be regarded as being on the average the same in all layers (the available does actually diminish with depth, but not significantly so). The significant decrease with depth in total phosphoric acid in perennial land is now seen to be almost wholly accounted for by the decrease in the available; the residual phosphoric acid (given the present number of observations) does not diminish significantly with depth nor does it anywhere differ significantly from that present in basin land.

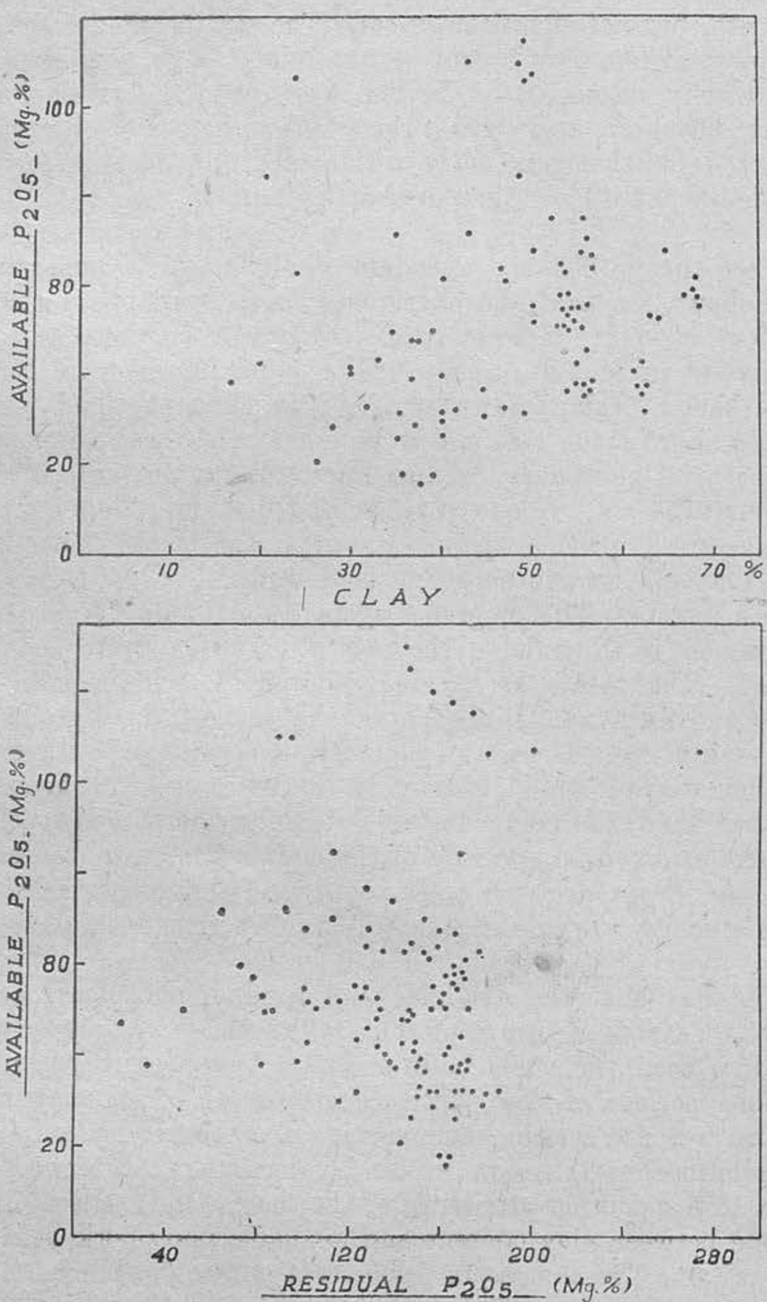
When the profiles are considered individually it appears that, as was shown for total phosphoric acid, both available and residual phosphoric acid are characteristic features of each profile so that the amount present in one layer is an index of what will be found in the others. This is illustrated for available phosphoric acid in Figure 2 and for the residual in Figure 3. In these figures, as was done for total phosphoric acid in Figure 1, the amounts present in the first (0–25 cm.) second (25–50cm.) and third (50–75 cm.) layers are successively plotted against those present in the bottom (75–100cm.) layers, the two classes of land being of course treated separately as before. The diagrams again demonstrate the progressive improvement in the value of the association as the layers come closer together. The points for residual phosphoric acid in both types of land and for available phosphoric acid in basin land group themselves well about the lines of equality in accordance with the fact that their average amounts tend to be the same in all layers. On the other hand, the points for available phosphoric acid in perennial land are displaced to one side of the equality lines, in consequence of the significant decrease with depth, and the deeper subsoils are clearly moving towards a state of uniform exhaustion.

The fact that the available and residual phosphoric acid are each characteristic features of the profiles means that at any given point in a basin the same conditions must have persistently recurred over long periods of time, since a metre depth of soil may roughly be taken to represent the accumulation of a thousand years (1). The only relationship that can so far be demonstrated between phosphoric acid and other attributes of the (basin land) soils is the positive one between clay content and available phosphoric acid shown in Figure 4. The association becomes significant, although not very strong ($r=+\cdot38$), only if the points for six samples yielding exceptional amounts of available phosphoric acid for the clay they contain are excluded from the calculation. Four of these samples belong

(1) John Ball in "Contributions to the Geography of Egypt" (Cairo, Government Press, 1939). p. 176, takes the rate of deposition as nine centimetres per century.

BASIN LAND SOILS

FIG. 4



to a profile from a basin at Qous in Qena Province (two profiles were taken from this basin and both show this feature of high available phosphoric acid). There is also an inverse relationship (Figure 4) between the residual and the available phosphoric acid; it is even weaker than the one between the available phosphoric acid and the clay and becomes significant (at r=—·27) only if the results for the two profiles at Qous are neglected. From this negative relationship it may be inferred that the "residual" phosphoric acid is positively associated with for example the fine sand fraction, *i.e.* it exists in the soil in the mineral form. This cannot actually be demonstrated since the complete mechanical analysis of the basin land samples was not carried out, only the clay being determined. (It may be noted that there is a reasonably good positive association between total and available phosphoric acid for all layers of basin land and for the surface, but not the deeper, layers of perennial land which can be disregarded; as shown above, when the comparison is reduced to one between the residual and available forms, the relationship is actually negative.)

Exhaustion of Perennial Land

Returning to the nature of the distribution of the available phosphoric acid a further aspect brought out by Figure 2 is the greater diversity of the subsoils of basin land as compared with perennial. This can be expressed as follows:—

For available phosphoric acid in the 75–100 cm. layers:—

	Degrees of freedom	Variance	1/2 loge
Basin Land	18	28·94	1·6827
Perennial Land	22	6·136	0·9071
			Z = 0·~~756~~ 7756 (P=< ·001)

The surface (0–25 cm.) layers of the perennial land profiles on the other hand are significantly more variable than those of the basin land profiles:—

For available phosphoric acid in the 0–25 cm. layers:—

	Degrees of freedom	Variance	1/2 loge
Basin Land	18	21·16	0·3750
Perennial Land	22	49·49	0·7997
			Z = 0·4247 (P=< ·05)

i.e., the original diversity of the subsoils of land now under perennial irrigation has been much reduced by abstractions of available phosphoric acid while that of the surface layers has been increased by additions to a varying extent. The available phosphoric acid content of the subsoils of perennial land may be regarded as moving towards one common (low) level.

It must be considered unlikely that any additions of phosphoric acid to the surface layers of perennial land will penetrate to a depth greater than twenty-five centimetres, if indeed they can penetrate thus far. The altered nature of the distribution of the available phosphoric acid in perennial land is due to the intervention of plant roots. As root systems successively grow, die and are decomposed the return they make of available phosphoric acid will be greatest in the surface layers and will diminish with depth. More phosphoric acid is continually being removed (in the aerial parts of plants) from the soil profile than is being returned to it but the relative loss is greatest in the lowest layer. As exhaustion proceeds in the lowest layer the layers above it are of course also becoming affected but to a progressively lesser extent as one moves upwards to the surface. When the available phosphoric acid content of the deeper layers has been reduced to or below the level (about 30mg. phosphoric acid per cent) which will be shown to be deficient for plant growth by the Aspergillus niger method, further reduction there becomes slow. The process of impoverishment of the soil profile will then still go on until the successive layers of the soil up to and including the surface (supposing there to be no phosphoric acid additions there—which will not normally be the case) are eventually reduced to the same deficient state.

The reduction of the available phosphoric acid of the subsoil in this way is permanent. The only possible further source of supply would be from the "residual" phosphoric acid which has been shown to be not altogether insoluble in citric acid. As already stated it is unlikely that surface additions of phosphoric acid would penetrate even so deeply as twenty-five centimetres.

The various stages of exhaustion are illustrated below by individual profiles from the perennial land series averaged in Table II, beginning with the most deficient. The latter possess subsoils that are uniformly exhausted, overlain by surface soils which are better supplied, and may be quite rich. The last is an example of a profile from soils which are occasionally met with and which are exceptionally rich.

TABLE III

Examples of Profiles from Perennial Land

Soil No.	Locality	Depth of layer	Total P_2O_5 per cent	Gm. mycelium per 20 g. soil in Aspergillus niger test	Equal to available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent
C 37	Kasr el Gard	0– 25	0·170	2·10	31	139
No. 19	(Gharbia)	25– 50	0·165	1·66	23	142
		50– 75	0·168	1·64	23	145
		75–100	0·164	1·59	22	142
C 37	Tablouha	0– 25	0·251	4·13	88	163
No. 34	(Menufia)	25– 50	0·214	1·75	25	189
		50– 75	0·201	1·79	26	175
		75–100	0·202	1·72	25	177
W 38–39	Tombara	0– 25	0·159	2·39	41	118
No. 4	(Gharbia)	25– 50	0·172	2·23	37	135
		50– 75	0·163	1·91	29	134
		75–100	0·150	1·83	27	123
C 38	Bourgaya	0– 25	0·217	3·68	73	144
No. 43	(Minia)	25– 50	0·183	3·01	55	128
		50– 75	0·175	2·02	30	145
		75–100	0·179	1·74	25	154
C 38	Gimmeiza	0– 25	0·199	2·81	50	149
No. 1	(Gharbia)	25– 50	0·170	2·75	47	123
		50– 75	0·165	2·52	43	122
		75–100	0·142	2·33	39	103
C 37	Mushtohor	0– 25	0·290	5·98	200	90
No. 36	(Quliubia)	25– 50	0·302	6·00	200	102
		50– 75	0·244	4·87	120	124
		75–100	0·211	3·82	77	134

Three basin land profiles, also included in the averages given in Table II, are quoted here (Table IV) to emphasise the variety of conditions that may exist before perennial irrigation begins. The profile from Sohag is already very deficient in available phosphoric acid while the one from Qous is extremely well supplied. The latter is the profile yielding the very unusual amounts of available phosphoric acid for the clay it contains and so disturbing to the relationship between these two factors shown in Figure 4.

TABLE IV

EXAMPLES OF PROFILES FROM BASIN LAND

Soil No,	Locality	Depth of layer.	Total P_2O_5 per cent	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent	Clay content per cent
		cm.				
536	Sohag (Girga)	0– 25	0·164	21	143	26·1
		25– 50	0·178	18	160	35·7
		50– 75	0·177	16	161	37·7
		75–100	0·180	18	162	39·2
		100–150	0·175	27	148	39·5
		125–150	0·182	33	149	47·2
563	Hod el Zemar (Assiut)	0– 25	0·224	58	166	66·5
		25– 50	0·225	58	167	68·0
		50– 75	0·224	59	165	67·5
		75–100	0·217	62	155	68·3
		100–125	0·221	55	166	68·5
568	Qous (Qena)	0– 25	0·286	106	180	49·0
		25– 50	0·305	107	198	49·6
		50– 75	0·289	115	174	49·0
		75–100	0·380	107	273	23·8
		100–125	0·253	85	168	20·6
		125–150	0·239	63	176	23·9

It may be pointed out here that the relative variability of surface and subsoil is of practical importance when the results of the cotton and wheat experiments come to be considered. When cotton responds significantly to superphosphate it is found that the available phosphoric acid sinks below a certain value somewhere in the subsoil. Such deficient subsoils will represent a selection at one extreme of the range and will show scarcely any variation compared even with the general run of perennial land. As against this the surface layers overlying these deficient subsoils, while on the average less well supplied than the surface layers of soils where there was no significant response (see Table XII), will still remain very variable. From the practical point of view the association between surface and bottom layers in such profiles will have largely been lost so that it will be impossible to say, from an examination of the surface layers, whether they are deficient in phosphoric acid for cotton and wheat or not, except in the rare cases where these surface layers are themselves deficient. When all subsoils become uniformly exhausted this difficulty will no longer obtain.

Rate of Exhaustion

More phosphoric acid, as is demonstrated below, is on the whole continually being removed from perennial land than is being returned to it. The great variability shown by the profiles makes it difficult to form an estimate of the rate at which this exhaustion is proceeding because of the sampling error involved. It must remain a matter for speculation, for example, as to what relationship the present average state shown by the profiles of perennial land of Table II bears to their original condition or to the mean for perennial land as a whole. Apart from those given here the only other extensive analyses published are by Hughes[1] and by Hughes and Aladjem[2] for surface soils. Hughes gives the mean of seventy-eight samples from Gharbia and Menufia as :—

	Total Phosphoric Acid per cent	Available Phosphoric Acid per cent
	0·26	0·033
(Highest and lowest values found)	(0·45–0·13)	(0·083–0·003)

and the mean of eleven samples from Armant as :—

	0·35	0·066

(The available phosphoric acid was determined by Dyer's method using one per cent citric acid, i.e., no allowance was made for the calcium carbonate present so that the results are not on the same basis as the ones given here.)

The Armant samples are comparable with the Qous profile of Table IV for high content of phosphoric acid.

Hughes and Aladjem state that, for "the average soil of the Delta 0·24 per cent may be taken as the total amount of phosphoric acid of which about 0·04 is soluble in one per cent citric acid solution."

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(1) "Notes on Egyptian and Sudan Soils", by Frank Hughes-Year-Book of the Khedivial Agricultural Society, 1906 : p. 131.

(2) "The concentration of Phosphoric Acid in the Soil in the Neighbourhood of the Old Centres of Population," by Frank Hughes and Raphael Aladjem. The Agricultural Journal of Egypt, Vol. I, p. 81 (1911).

These figures for total phosphoric acid are considerably higher than those given in Table II whether for basin or perennial land. The comparable figures for available phosphoric acid can safely be presumed to be much higher also.

The most useful picture that can be given here (for available phosphoric acid) is that drawn from one hundred and eighty profiles examined by the Aspergillus niger method in connection with field experiments. These have been divided into five groups : one being in Upper Egypt and four, according to latitude, for the Delta. The average content of available phosphoric acid in these five groups, moving from north to south is :—

TABLE V

AVAILABLE PHOSPHORIC ACID IN PERENNIAL SOILS.

(Figures are Milligrams Phosphoric Acid Per 100 G. Soil.)

	North of lat. 31°00'	Between lat. 30°45' and 31°45'	Between lat. 30°30' and 30°45'	Between lat. 30°00' and 30°30'	Upper Egypt
Gronp No,	1	2	3	4	5
No. of profiles in group	46	40	24	28	42
C.S.S. (1)	60	55	63	67	72
0 — 25cm.	55	51	57	58	67
25— 50 ,,	44	40	40	44	49
50— 75 ,,	38	35	32	38	42
75—100 ,,	35	31	31	35	40

(1) C.S.S. = Composite surface sample.

Leaving out the group north of latitude 31°00', i.e. the group lying north roughly of a line drawn through Damanhour and Mansoura, there is a progressive increase in available phosphoric acid as one moves from north to south. This may also be expressed by saying that the soils in groups 2 and 3 from the middle of the Delta are poorest. All groups must, on their averages, be considered to represent soils that are still well supplied with available phosphoric acid and in the case of group 5 from Upper Egypt very well supplied. The only layers approaching the limit of deficiency established by the field experiments are the bottom ones of groups 2 and 3. The average for the one hundred and thirty-eight profiles from the Delta of Table V is not very different, apart from a lower content in the surface layer, from that for the perennial soils of Table II; it is therefore lower than the figure presumed for available phosphoric acid from the analyses of Hughes and Aladjem. (1)

In the Bahtim (2) permanent experiments laid down in 1912 a study has been made of the rate at which the available phosphoric acid, in the absence of phosphatic manures, becomes so reduced in a soil as to render phosphatic manuring beneficial. The soil on which the experiments were laid down is described as being "rich" but as no actual analyses were then carried out this may mean no more than that it had been in the way of receiving more baladi manure than the average; there are indications that it may actually have been poor from the (subsoil) point of view developed here. Ahmed Mahmoud, reporting on these experiments(2), says that (compared with plots receiving no phosphoric acid at all), "It was found that bersim began to respond to phosphate manuring five or six years after the initial application of the phosphatic fertiliser, wheat and cotton 10 or 12 years after while the crop which suffered least from phosphoric acid deficiency in the soil was maize".

Additions to Surface Soils

It has already been seen that the diversity of the surface layers of perennial land has increased as compared with those of basin land in consequence of additions of phosphoric acid to a varying extent. The most important single source of these additions is the phosphoric acid contained in baladi manure. Other sources are sebakh koufri and superphosphate.

Beladi Manure.—From the number of animals kept in the country it is calculated that the amount of beladi manure annually produced will be of the order of one hundred million cubic metres or about seventy million tons. (This figure is based on the number of animals given for 1940 in the "Annuaire Statistique"; the number increased markedly over the previous twenty years.) The total phosphoric acid contained in beladi manure varies from 0·2 to 0·6 per cent

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(1) *loc. cit.* p. 15.

(2) "Preliminary Investigations on the Phosphoric Acid Supply in the Soils of the Bahtim Permanent Experiments," by AHMED MAHMOUD. *Bulletin No.* 20. Chemical Section. Royal Agricultural Society (1934).

and the available from 0·050 to 0·200 per cent, a varying part of which will of course already have been present before the earth was put underneath the animals. If the available phosphoric acid added in the course of making the manure be put at 0·035 per cent(1) then the contribution of the seventy million tons of beladi manure will be twenty-five thousand tons of phosphoric acid. Spread over four million feddans (the million feddans still under the basin system will receive very little) this means an average annual return to each feddan of about six kilos of available phosphoric acid. It is possible that the importance of beladi manure in maintaining the available phosphorus supply in surface Egyptian soils has been insufficiently realised in the past. The practice of making the solid faeces into manure cakes (gillah) for fuel may have led to an underestimate of the possibilities(1). Thus J.A. Prescott(2) in " Farmyard manure in Egypt " deals solely with the conservation and utilisation of the nitrogen it contains ; the phosphoric acid present is barely mentioned in an Introductory Note by Victor M. Mosséri although he actually discusses phosphatic manuring. Its value as a phosphatic fertiliser has been clearly recognised by Ahmed Mahmoud(3) but no analyses are given nor any estimate made of the possible amount of its contribution.

In this connection the patchwork appearance in the month of January of a field of berseem which had followed maize rented out to small cultivators is instructive. The maize crop usually receives a large part of the beladi manure, and the varying resources of the individual tenant in the amount and quality of that material at his disposal were clearly reflected in the growth and colour of the berseem. The colour varied from the deep purple bronze associated with phosphorus deficiency in berseem in cold weather through lighter shades of it up to the dark green colour and increased growth of a more adequate supply.

Sebakh Koufri.—The exploitation of the koms or mounds marking the sites of former villages and towns as a source of manure (sebakh

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(1) This very approximate estimate is based on the examination of twenty-seven samples of beladi manure from as many localities distributed throughout the country. The average content in available phosphoric acid of these twenty-seven samples was 93 milligrams per cent. If the amount already present in the earth before it was put beneath the animals is assumed to be the same as the average for the surface layers of the one hundred and eighty profiles of Table V at 58 milligrams per cent, then 35 milligrams will have been added in the course of making the manure. By no means all of the solid faeces are removed and used as fuel. The average amount of total nitrogen contained in beladi manure ranges from 0·3 to 0·6 per cent of which the soluble nitrogen accounts for say 0·12 per cent and 0·08 per cent may have originally been present in the earth.

(2) " Farmyard Manure in Egypt ", by J.A. Prescott, Bulletin No. 8, Sultanic Agricultural Society (1921).

(3) Loc. cit. p. 17.

koufri) is a very old practice. Its importance as a source of phosphoric acid is diminishing as the more accessible of the koms gradually become exhausted; and accessibility in this connection essentially means the limits imposed by transport by donkeys or, at best, camels. The influence of a kom on the phosphoric acid content of the land surrounding it has been studied by Hughes and Aladjem(1), who give the following figures :—

Distance from centre of kom in kilometres	Samples examined	Average total phosphoric acid per cent	Average soluble phosphoric acid per cent
0—1	5	0·34	0·086
1—2	16	0·29	0·069
2—3	9	0·26	0·065
3—4	9	0·22	0·051
4—5	9	0·22	0·036

These authors also point out that the proportion of the available to the total phosphoric acid in samples from the kom was exceptionally high. V.M. Mosséri (2) made a survey of kufris from numerous koms. He found them, as would be expected, extremely variable in composition but that they could be very good sources of available phosphoric acid. No estimate is made of the quantities annually contributed from this source but they were already noted by Mosséri in 1921 as being of diminishing importance.

Superphosphate.—The third main source of supply of phosphoric acid is superphosphate. The eighty-six thousand tons of 16–18 per cent superphosphate imported in 1936 contained roughly thirteen thousand tons of phosphoric acid which, spread over four million feddans, means a contribution of about three kilos of phosphoric acid per feddan or about a half of that furnished by beladi manure (nothing like this quantity of superphosphate, of course, was available during the war years).

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(1) "The Concentration of Phosphoric Acid in the Soil in the Neighbourhood of the Old Centres of Population," by FRANK HUGHES and RAPHAEL ALADJEM. The Agricultural Journal of Egypt, Vol. I., p. 81 (1911).

(2) "Le Sebakh des Koms ou Sebakh Koufri," par VICTOR M. MOSSERI, "*Bulletin de l'Institut d'Egypte* (1921).

Amounts Annually Lost

Against these additions, if a three-year rotation of cotton followed by wheat then maize, berseem and maize be assumed, there is removed phosphoric acid of the order of eighty kilos per feddan every three years, one or say hundred thousand tons from four million feddans per annum. Of this amount half will be contained in the grain and cotton seed sold off and half will remain on the farm with the berseem, cereal straw, cotton sticks and maize stalks. If the amount brought in as superphosphate — taken as thirteen thousand tons — is deducted, and the contribution of sebakh koufri neglected, there is a steady annual drain away from the four million feddans of perennial land of about thirty-seven thousand tons of phosphoric acid. The actual loss to the soil is much greater than this since only part (one-half or twenty-five thousand tons according to the calculation on page 18) of the fifty thousand tons remaining on the farm will find its way into the beladi manure.

FIELD EXPERIMENTS WITH SUPERPHOSPHATE

Mineral Phosphates Ineffective

Phosphate deposits are worked in Egypt at Sebaia in Qena and at Safaga and Qosseir on the Red Sea coast for export as ground mineral phosphates. The question has naturally often been raised of using these ground mineral phosphates either as such or in admixture with sulphur and gypsum (as in e.g. thiophosphate) in place of the more expensive superphosphate. As Egyptian soils always contain calcium carbonate and, if normal, show PH values of 8·3 or 8·4 (soil : water ratio of 1 : 2·5) it is inherently unlikely that ground mineral phosphate would be effective as a manure and this in fact is found to be the case. The difficulty in making satisfactory comparisons between soluble and insoluble phosphates lies in ensuring that the land chosen for the experiments will show a good response to superphosphate; the alternative is to conduct the comparisons at as many centres as possible in the hope that this condition will be fulfilled at some. Experiments were conducted on cotton at seventeen localities in 1930 and at thirteen in 1931. The treatments consisted in superphosphate, ephos and thiophosphate(1)given in equivalent amounts alone and along with nitrate of lime, together with plots receiving nothing and plots receiving nitrate of lime alone. Both of the years, but especially 1931, were poor seasons for response to fertilisers with cotton. The average results of the experiments were :—

EXPERIMENTS WITH PHOSPHATIC MANURES ON COTTON
(YIELDS ARE IN KANTARS PER FEDDAN) (2)

1930 (Average of Seventeen Experiments)

	No phosphate	118 kg. Ephos	178 kg. Superphosphate	184 kg. Thiophosphate
No nitrate of lime ...	4·71	4·87	4·87	4·81
100 kg. nitrate of lime	5·09	5·11	5·40	5·11

(1931 (Average of Thirteen Experiments)

	No phosphate	120 kg. Ephos	180 kg. Superphosphate	184 kg. Thiophosphate
No nitrate of lime ...	4·32	4·46	4·52	4·49
100 kg. nitrate of lime	4·87	4·94	4·91	4·94

In 1931 the phosphatic manures were without much effect whether given by themselves or in combination with nitrate of lime. In 1930 on the other hand superphosphate increased the yield in the presence

(1) *Ephos* is a ground mineral phosphate containing thirty per cent phosphoric acid from Safaga on the Red Sea coast. It is claimed to contain radio active material.

Thiophosphate was a local product, containing seventeen per cent phosphoric acid, consisting of a mixture of ground mineral phosphate, gypsum and sulphur, which had passed through a 200 mesh sieve.

(2) A feddan is an acre, nearly. A kantar of cotton is approximately 99 lb. of lint.

of nitrate of lime by 0·30 of a kantar per feddan over nitrate of lime given alone or in combination with either of the other two phosphatic fertilisers. This effect from superphosphate, the average of seventeen observations, is judged significant. None of the three forms of phosphate had more than a slight effect when given alone.

Five experiments were carried out in 1932 on the effect on the following cotton of manuring berseem plots with five different forms of phosphatic manure, the cotton itself grown on these plots receiving no further treatment. The experimental lay-out was a six-sided latin square with plots one twenty-fourth of a feddan in area. The results of these five experiments were :—

1932 Experiments

Effect on (Following) Cotton of Phosphatic Manures Given to Berseem Catch Crop

(Yields are in Kantars per Feddan)

Locality	No manure	300 kg. superphosphate	300 kg. thiophosphate	200 kg. Safaga phosphate	200 kg. Qosseir phosphate	200 kg. Sebaia phosphate	S.E.
Sakha	3·57	4·24	3·84	3·65	3·90	3·45	0·14
Ezbet Khorshid	3·99	4·25	3·94	3·91	3·82	4·01	0·14
Average of five	4·64	4·82	4·70	4·63	4·63	4·61	—

A positive significant result on cotton was obtained at one centre (Sakha) only and with superphosphate. There was an indication of the same result in the experiment at Ezbet Khorshid. At the remaining three centres the results were extremely even and there was nothing in it. No records were made of the plot yields of berseem in the experiments but at Ezbet Khorshid for example it was noted that the only phosphatic manure having any apparent effect was superphosphate.

Observations on this question have also been made by Hughes (1) and by Ahmed Mahmoud (2).

Hughes grew berseem in a mixture of soil and sand in boxes 1m. square and 50 cm. deep. He obtained an increase in yield of 45 per cent due to the application of superphosphate while ground mineral phosphate produced scarcely any effect.

Ahmed Mahmoud laid down trials in 1930 on land (at Bahtim) known to be so deficient in available phosphoric acid that a good response to superphosphate at least was certain. The phosphatic manures compared included, in addition to ordinary (16–18 per cent) and concentrated (40 per cent) superphosphates, ephos and thiophosphate (see above) sulphurophosphate, a French product consisting of mineral phosphate and sulphur, basic slag (16 per cent phosphoric

(1) Frank Hughes, "Notes on Egyptian and Sudan Soils". Year-Book of the Khedivial Agricultural Society, 1906.

(2) Ahmed Mahmoud, "Phosphatic Fertilisers, Comparative Trials on Immediate and Residual Effects", Bulletin No. 21, Chemical Section, Royal Agricultural Society (1934).

acid) and a bone meal containing 29 per cent phosphoric acid. The most effective fertilisers were ordinary and concentrated superphosphates in which the phosphoric acid was of equal value. Basic slag was also effective but the increase in yield (of berseem) in the first year was only half that from the superphosphates. The other phosphates containing their phosphoric acid in an insoluble form did not show any effect, direct or residual, over a period of five years.

At about the time that these comparisons of mineral phosphate with superphosphate were being made the idea was still tenaciously held by some that Egyptian soils were naturally so rich in available phosphoric acid that the addition of more as superphosphate was unnecessary. The beneficial effect of superphosphate (the use of which had been spreading in some localities) was asserted to be due to the calcium sulphate (gypsum) it contained. Thus Victor M. Mosséri [1] states that some of the soils on which benefit (berseem and beans) was being experienced in Sharqia were slightly alkaline and that " the use of gypsum could well replace that of superphosphate in many of these cases ". From the analysis of the situation given here the reflection would be that many of the soils in Sharqia are well known to be lighter than the average and would therefore, from the positive relationship between clay and available phosphoric acid (Fig. 4), tend to be low initially in that nutrient. It is in any case scarcely conceivable that the small amount of gypsum contained in an ordinary dressing of superphosphate could cause the immediate reduction in soil alkalinity necessary to occasion the yield effects discounted. Nevertheless some six experiments were conducted on the point (superphosphate versus gypsum) on cotton and maize in 1931 and1932, with negative results. Moreover the thiophosphate, always included in the comparisons of mineral phosphates with superphosphate, and as ineffective as the others, contains gypsum and sulphur. The latter on addition to the soil will undergo rapid change and is best regarded as being a further source of gypsum.

From the above it is concluded that where there is real need for available phosphoric acid ground mineral phosphates are quite unable to meet it and superphosphate, for which gypsum is no substitute, must be used. While superphosphate thus appears to be the only effective phosphatic fertiliser at the present time it is not necessarily fully efficient. The superphosphate made in Egypt from mineral phosphate from Sebaia will contain acertain a mount of fluorine so that some of the soluble phosphate may become relatively unavailable again as calcium fluophosphate on addition to the soil. [2]

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[1] VICTOR M. MOSSÉRI, Introductory N ote to " Farmyard Manure in Egypt " by J. A. PRESCOTT. *Bulletin No. 8 of the Sultanic Agricultural Society* (1921).

[2] A New Explanation of what happens to Superphosphate on limed Soils." W. H. McINTIRE. Tennessee Agric., Expt. Sta., Bull. 176 (1941). *Egyptian soils always contain calcium Carbonate.*

Results of Field Experiments—General

The behaviour of the main agricultural crops to manuring with superphosphate in the field experiments is summarised in the following table :—

TABLE VI

AVERAGE EFFECTS FROM SUPERPHOSPHATE[1]

Crop	Number of Expts.	Number of Years	Number of Expts. showing significant positive response	Per cent of Expts. showing significant positive response	Number of Expts. showing significant negative response	Average direct effect on yield per feddan
						from 1 P
Berseem	53	6	37	69·8	none	3·44 tons
Beans	53	6	21	39·6	none	0·65 ardebs
Rice	124	10	70	56·4	1	1·33 ardebs
						from 2 P
Cotton	426	14	110	25·8	10	0·18 kantars
Wheat	288	11	93	32·2	9	0·29 ardebs
Barley	148	11	36	24·3	4	0·36 ardebs
Maize	291	12	62	21·3	11	0·24 ardebs

[1] Note : The level of probability taken for significance throughout is P=·05.

1P = 100 kg. superphosphate per feddan.

2P = 200 „ „ „ „

The equivalents of the weights and measures used are :—

1 feddan = 1·038 acres.
= 4.200 sq. m.

1 ardeb of rice (undec.) = 120 kg.
1 „ „ wheat = 150 „
1 „ „ beans = 155 „
1 „ „ barley = 120 „
1 „ „ maize = 140 „
1 kantar „ cotton = 100 rotls = 99 lb. lint approx.

The crops in the table naturally fall to be dealt with in two groups. Those in the first group, comprising berseem, beans and rice, show a much higher rate of positive significant response and a larger average yield effect than those in the second; moreover in only one experiment (with rice) is there recorded a significant depression in yield. In the second group, on the other hand, experiments showing a significant negative response are a feature of the results being roughly one-tenth of the number showing positive significant response with cotton and wheat, increasing to one-fifth of that number in the case of maize.

The berseem crop has by far the largest requirement in phosphoric acid of the seven crops given in the table, amounting to about 30 kg., phosphoric acid per feddan for a moderate (thirty-five ton) crop. This is twice the amount taken up by beans or maize and about three times that for average cotton or for each of the other three cereal crops (1). Beans and rice come in a class by themselves in that superphosphate has a lessened effect on their yield when given along with nitrogen than when given alone, a statement which applies equally to the nitrogen given separately and together with superphosphate.

The nature of the response of the other four crops will be shown to depend straightforwardly on the region of the soil mainly occupied by their roots in conjunction with the amount and distribution of the available phosphoric acid in the soil profile. Before a positive significant response is obtained with any of them a certain minimum value must be depassed somewhere in the subsoil. This value is about 2·00 g. mycelium per 20 g. soil in the Aspergillus niger method equivalent to 30 mg. (2) phosphoric acid per cent. Wheat and cotton may respond to superphosphate when the available phosphoric acid sinks below this "threshold" value anywhere within the total depth of one metre; for the shallow-rooted and quick-growing maize crop it has to occur within the top fifty centimetres if really substantial effects of superphosphate on the yield of maize are to be experienced. The nature of the interaction between nitrogen and superphosphate with these four crops is quite different from that found with beans and rice. Even allowing for what may happen in the individual experiment

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(1) *See*: "Manures in Egypt and Soil Exhaustion", by G. P. Foaden and W.C. Mackenzie Journal of the Khedivial Agricultural Society. Vol. I. 1899. The figure for rice is based on recent (unpublished) work done in the Chemical Section.

(2) This figure is of the same order as that given by Hughes and by Ahmed Mahmoud for surface soils.—*loc. cit.* p. 22.

the average effect on the whole of superphosphate given to plots receiving increasing amounts of nitrogen is to increase the efficiency of the nitrogen; the influence on the average yield is very small but the effect is quite definite.

Below are given fuller details of the yield effects from superphosphate in the field experiments with each of the crops of Table VI, in succession. The results of the examination of soil samples by the Aspergillus niger method are available for comparison with the yields recorded for some years only of the experiments with cotton, wheat, maize and rice. The soil samples consist of a composite surface sample taken from the control plots and four successive layers of 25 cm. each from a hole dug to a depth of one metre just off the edge of the experiment. As the latter may cover an area of one and a half feddans and Egyptian soils are very variable, the extent to which the subsoil samples represent conditions there is undetermined; they do of course achieve some success in this respect.

A final section is then devoted to a consideration of the influence of season (temperature) on the kind of response obtained. The significant negative effects noted above will be shown to have a tendency to occur in the warmer growing seasons and in the warmer parts of Egypt and positive response (with wheat *e.g.*) to be greater in cold weather.

Berseem Experiments

The series of experiments on the amount and time of application of superphosphate to berseem was begun in the winter of 1940 and is being continued. The layout is a six-sided latin square with plot size one-eightieth of a feddan. The five treatments, in addition to the control plots, are superphosphate at the rates of one and two hundred kilos per feddan applied at the two times of sowing and the first cutting and two hundred kilos given half at sowing and half at the first cutting. The factor of time of application was introduced because it is a fairly general practice to apply superphosphate to berseem after taking the first cutting.

The average results of the experiments for each year and for the whole period of six years are given in Table VII The figures are tons of green berseem per feddan.

TABLE VII

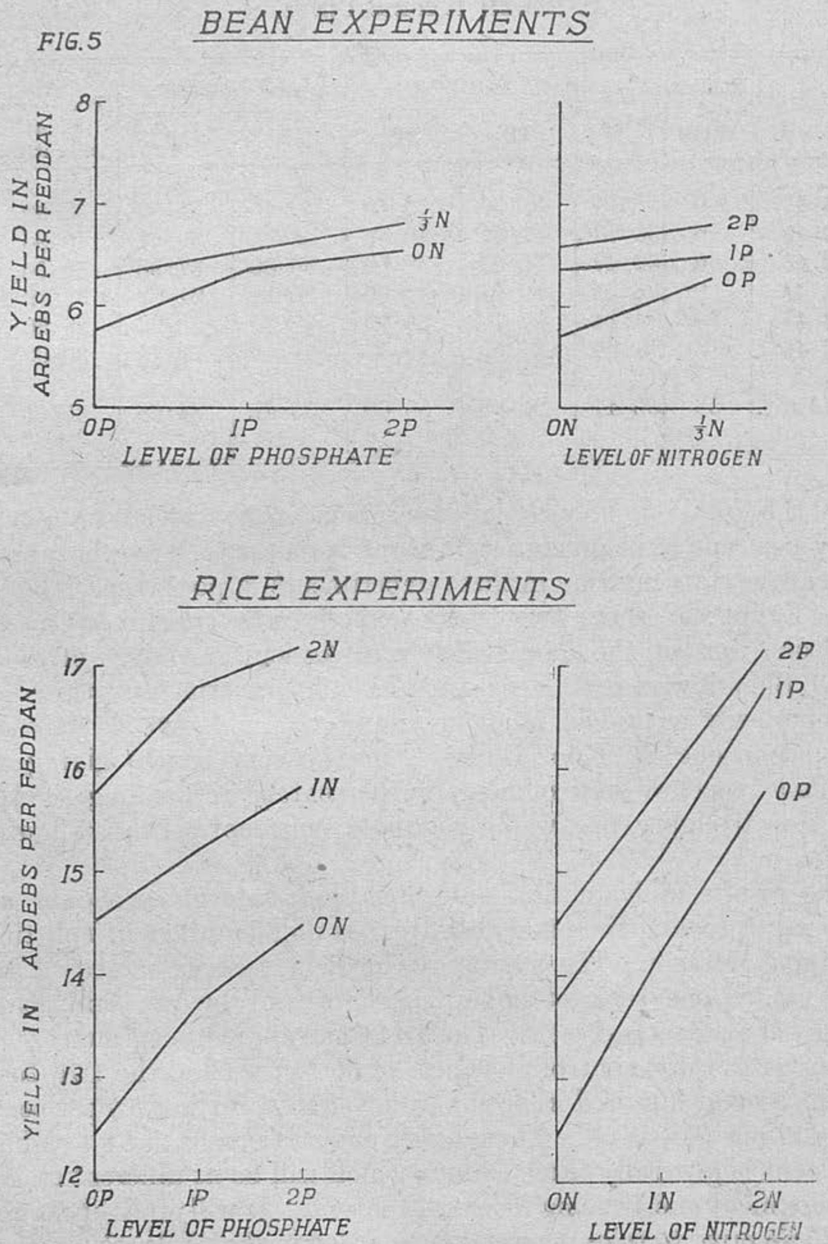
Berseem Experiments

Year	Number of Expts.	No manure	At sowing 1P	At sowing 2P	At 1st cutting 1P	At 1st cutting 2P	2P 1P at sowing 1P at 1st cutting
1940-41	10	28·14	31·55	32·46	30·45	31·57	32·69
1941-42	6	35·74	39·69	40·82	38·94	39·67	40·95
1942-43	6	33·47	36·87	39·50	36·30	37·96	39·16
1943-44	9	26·59	30·07	31·90	30·13	31·83	32·19
1944-45	10	34·14	37·15	38·99	37·28	38·32	38·66
1945-46	12	24·56	27·90	30·14	27·42	28·73	30·03
Average for six years...	53	30·44	33·88	35·63	33·42	34·68	35·61

Of the total of fifty-three experiments thirty-seven or about seventy per cent have given a significant response to superphosphate The locality representation in these experiments is poor especially in Upper Egypt; of the twenty-six experiments conducted there, twenty-one were at the four Ministry of Agriculture farms of Sids, Mallawi, Shandaweel and Mataana. If eight experiments (three at Serw on newly reclaimed land in the north and five — four at Mataana and one at Kom Ombo — in the very south) giving no significant response are excluded the percentage responding significantly rises to eighty-two, which may be a more representative figure.

The results indicate that any superphosphate given should all be applied at sowing time and that there is no advantage in splitting the larger dressing. The average yield of berseem is increased by 3·44 tons by one sack of superphosphate and by an additional 1.75 tons by the second sack. The 3·44 tons represents an increase of 11.3 per cent on the control plot yield of 30·44 tons and the 1·75 tons from the second hundred kilos superphosphate a further 5·7 per cent, making 17 per cent in all. The number of cuts taken in the individual experiment is generally three or four which will be at different stages of development and varying moisture content. It will probably not be seriously in error to take the weights recorded in the table as consisting as to four-fifths (eighty per cent) water and one-fifth dry matter. The 3·44 tons increase in green berseem will therefore represent about 700 kg. of dry matter per feddan; this is a larger dry matter increase from superphosphate than is shown by the average of any of the other crops.

FIG. 5


BEAN EXPERIMENTS
YIELD IN ARDEBS PER FEDDAN
8
7
6
5
$\frac{1}{3}$N
0N
0P
1P
2P
LEVEL OF PHOSPHATE
2P
1P
0P
0N
$\frac{1}{3}$N
LEVEL OF NITROGEN
RICE EXPERIMENTS
YIELD IN ARDEBS PER FEDDAN
17
16
15
14
13
12
2N
1N
0N
0P
1P
2P
LEVEL OF PHOSPHATE
2P
1P
0P
0N
1N
2N
LEVEL OF NITROGEN

Bean Experiments

Three levels of superphosphate are employed in these experiments (0, 100 and 200 kg. of 16–18 per cent superphosphate per feddan) and two levels of nitrogen (0 and 33 kg. — 5 kg. of nitrogen — of nitrate of soda per feddan) giving six treatments in all. The layout is a six-sided latin square with plot size 1/40th of a feddan. The superphosphate is applied at sowing and the nitrate given before the first watering after the sowing watering. The series of experiments was begun in 1940 and is being continued. The average results by years and for the whole period of six years, eliminating season, are as follows:—

TABLE VIII

RESULTS OF BEAN EXPERIMENTS

(Ardebs per feddan)

Year	Number of Expts.	0	1P	2P	$\frac{1}{3}$N 1P	$\frac{1}{3}$N 2P	$\frac{1}{3}$N
1940–41	4	6·38	6·83	7·09	7·21	7·38	7·25
1941–42	10	5·68	6·17	6·48	6·50	6·76	5·94
1942–43	6	6·49	7·37	7·25	7·05	7·47	7·07
1943–44	11	4·43	5·16	5·41	5·38	5·66	5·11
1944–45	12	5·70	6·57	6·63	6·54	7·02	6·54
1945–46	10	5·62	6·10	6·51	6·29	6·62	5·89
Average over six years ...	53	5·72	6·37	6·57	6·49	6·82	6·30

There are fifty-three experiments with beans altogether. In twenty-one of these or about forty per cent the direct effect of superphosphate is significant; in sixteen or thirty per cent the effect of the addition of five kilograms of nitrogen as sodium nitrate is significant while interaction reached significance in seven. The nature of the interaction on the average has already been referred to; it is illustrated in Fig. 5 drawn from the six years average given at the bottom of Table VIII. The average returns from one sack of superphosphate and from the third of a sack of nitrate of soda given separately are respectively 0·65 and 0·58 of an ardeb or in all 1·23 ardebs; given in combination the increased yield over the control plot is only 0·77 of an ardeb. The increase obtainable in individual cases whether from superphosphate or from the dressing of nitrate ranges up to two ardebs per feddan so that a more precise definition of the conditions under which it is obtainable might perhaps be worth while.

Rice Experiments

After the first year of these experiments the treatments have always consisted of three levels of nitrogen (0, 75 and 150 kg. of sulphate of ammonia) and three levels of phosphate (0, 100 and 200 kg. of superphosphate per feddan) giving in all nine treatments.(1) The layout is in six randomised blocks with plot size 1/40th of a feddan. The average results by years as well as for the whole period are given in Table IX : —

TABLE IX

RICE EXPERIMENTS

(Ardebs per feddan.)

Year	Number of Expts.	No nitrogen			75 kg. S/A			150 kg. S/A		
		0P	1P	2P	0P	1P	2P	0P	1P	2P
1937	10	13·65	15·70	—	15·56	17·00	—	16·80	17·61	—
1938	14	12·99	15·05	15·79	14·30	15·85	16·54	15·65	16·67	17·36
1239	11	14·14	15·07	15·72	15·96	16·45	16·56	15·16	17·56	17·81
1940	13	13·52	14·13	15·54	15·16	16·44	16·99	16·48	17·52	18·47
1941	11	13·65	15·13	15·39	15·69	16·42	17·13	16·57	17·58	17·76
1942	8	14·41	15·84	17·02	16·63	17·79	17·79	17·75	19·10	19·31
1943	14	7·96	8·93	9·77	9·91	10·80	11·10	11·46	12·20	12·77
1944	17	10·36	11·05	12·04	12·91	13·50	13·72	15·20	15·29	15·60
1945	13	10·82	12·51	12·64	12·97	13·59	14·31	13·96	15·32	15·48
1946	13	14·40	15·98	16·81	17·36	17·88	18·46	19·42	20·26	20·31
Average for 10 years	124	12·59	13·93	—	14·64	15·57	—	15·94	16·91	—
9 years	114	12·47	13·74	14·52	14·54	15·41	15·84	15·84	16·83	17·20
Average for Experiments conducted after Berseem										
Average for 21 expts.		15·75	15·91	—	17·65	18·12	—	18·57	19·20	—
Average for 18 expts.		16·07	16·04	17·19	17·94	18·47	18·96	18·96	19·58	20·12
Average for Experiments conducted after other Crops										
10 years (103 Expts.)		11·95	13.50	—	13·93	15·01	—	15·38	16·40	—
9 years (96 Expts.)		11·79	13·23	13·94	13·75	14·75	15.16	15·20	16·24	16·85

(1) The superphosphate is applied before sowing and the sulphate of ammonia three weeks after sowing.

Of the one hundred and twenty-four experiments with the rice crop, the results of which are averaged in Table IX, seventy, or fifty-six per cent, have given a significant positive response to superphosphate. The effect, as with beans, is not a straightforward one. One sack of superphosphate and seventy-five kilos of sulphate of ammonia respectively increase the yield by 1·27 and 2·07 ardebs per feddan or in all 3·34 ardebs whereas given together the actual total effect is only 2·94 ardebs. Similarly two sacks of superphosphate and one hundred and fifty kilos of sulphate of ammonia given separately increase the yield respectively by 2·05 and 3·37 ardebs making in all 5·42 ardebs as against the 4·73 ardebs recorded when they are used in combination (*see* Fig. 5).

Thirteen profiles from the 1938 rice experiments, in nine of which there was a significant positive response to superphosphate, have been examined by the Aspergillus niger method for available phosphoric acid.

TABLE X

RICE EXPERIMENTS 1938

Grams mycelium per 20g., soil in Aspergillus niger test

(*a*) Experiments showing a significant positive response :—

Locality	Kafr el-Sheikh	Damat	Tombora	Gabaris	Marg	Ekiad	Tarout	Balamoun	Mit el Faranawi	Average of nine
Yield effect from 2P: ardebs per feddan ...	0·70	2·50	1·15	4·87	3·35	4·83	5·58	2·50	2·84	—
Depth of layer (cm.)										
C.S.S.	2·08	2·27	2·27	3·20	5·20	5·03	2·10	2·25	5·37	3·31
0– 25	1·70	2·13	2·23	2·23	5·48	5·00	1·95	2·13	5·08	3·10
25– 50	1·69	1·95	2·25	1·72	5·80	2·24	1·57	1·87	3·85	2·55
50– 75	1·68	1·82	2·85	1·60	5·93	1·85	1·58	1·56	1·90	2·31
75–100	1·64	1·73	2·93	1·50	5·73	1·72	1·45	1·53	1·73	2·22

(*b*) Experiments showing no significant response :—

Locality	Gimmeiza	Sakha	Itai el Baroud	Edfina	Average of four	Average overall
Yield effect from 2P: ardebs per feddan	+1.34	—0.21	+1.13	+0.54	—	—
Depth of layer (cm)						
C.S.S.	3·23	4·47	1·72	3·32	3·19	3·27
0– 25	2·10	4·52	1·38	2·46	2·62	2·95
25– 50	2·02	3·46	1·51	2·63	2·41	2·50
50– 75	1·60	2·04	1·37	3·25	2·07	2·23
75–100	1·50	1·95	1·60	2·95	2·00	2·15

Table X shows that the four giving no significant response are on the average no better supplied with available phosphoric acid than the nine giving a significant one; one of the four (from Itai el Baroud) is actually the poorest in available phosphoric acid of the whole thirteen while the richest is the profile from Marg where a significant response was obtained. The average of the nine profiles from the experiments responding significantly is not very different from the average of Delta profiles in Table XII from cotton experiments giving no significant response.

The effect of superphosphate on rice can be further analysed (Table IX) by splitting up the experiments into twenty-one conducted after berseem and one hundred and three after other crops such as wheat and beans. The average effect of superphosphate in the twenty-one experiments after berseem is much reduced compared with the rest totalling little more than one ardeb from *two sacks*, although the effect from seventy-five kilos of sulphate of ammonia is not much lower at 1·90 ardebs. The average effect of superphosphate (seasonal influence eliminated) in the hundred and three experiments after other crops is correspondingly increased and becomes roughly 1·4 ardebs from *one sack*. In ordinary times first consideration in the manuring of rice grown after crops such as wheat or beans would obviously therefore, from the point of view of cheapness in relation to the effect produced, be given to superphosphate.

Cotton Experiments

The manurial experiments with the cotton crop assumed their present form in 1933 (experiments on the same scale have actually been running since 1931). They employ five levels of nitrogen (0, 1, 2, 3 and 4 sacks of nitrogenous fertiliser each supplying 15·5 kilos of nitrogen per feddan) and two levels of superphosphate (0 and 2 sacks of the 16–18 per cent fertiliser) giving in all ten treatments. The layout is in six randomised blocks with plot size 1/40th of a feddan so that the direct effect of the superphosphate is measured from totals of thirty plots. The superphosphate is worked into the south side of the ridge before sowing and the nitrogen applied about one and a half months later, at thinning.

The effect of superphosphate in four hundred and twenty-six of these experiments carried out during the fourteen years 1933–1946 is summarised in table XI; the results for the Delta and Upper Egypt have been separately treated.

TABLE XI

Cotton Experiments

Yeaz	Number of Experiments	Number in Delta	No. positively significant in Delta	Number in Upper Egypt	No. positively significant in Upper Egypt	Average direct effect in kantars per feddan		
						Delta	Upper Egypt	Overall
1933...	29	19	4	10	0	0·33	0·07	0·24
1934...	25	18	5	7	2	0·22	0·12	0·19
1935...	25	21	7	4	0	0·23	0·11	0·21
1936...	35	27	9	8	0	0·17	-0·01	0·13
1937...	29	20	4	9	0	0·17	0·04	0·13
1938...	31	21	9	10	1	0·19	0·04	0·14
1939...	22	16	8	6	2	0·21	0·11	0·18
1940...	36	22	10	14	3	0·18	0·16	0·17
1941...	35	21	3	14	3	0·22	0·14	0·19
1942...	28	15	1	13	3	0·08	0·23	0·15
1943...	33	20	3	13	4	0·17	0·28	0·22
1944...	30	16	2	14	5	0·04	0·12	0·08
1945...	34	20	6	14	2	0·15	0·18	0·16
1946...	34	21	10	13	4	0·42	0·15	0·32
Totals and averages ...	426	277	81 or29·2%	149	29 or19·4%	0·20	0·12	0·18

The proportion showing significant response — 29 per cent — and the average yield effect — 0·20 of a kantar per feddan — are greater in the Delta than in Upper Egypt where the respective figures are 19 per cent and 0·12 of a kantar. That this is so is entirely due to the first seven years of the fourteen and had the comparison been limited in time to these seven years, the difference between the two regions might have been judged to be considerable. In the second seven-year period the percentage responding significantly and the average yield effects (at about 25 per cent and 0.18 of a kantar) are the same for both regions ; this will also be seen to be roughly true of the results for the eleven years of the wheat experiments and may therefore be more nearly correct.

Estimations of available phosphoric acid have been made on the soil profiles from one hundred and nineteen experiments for the four years 1935–1938. The results for individual experiments are given in tables in the appendix and averaged in Table XII. Those in the appendix show that where cotton has responded significantly to superphosphate the yield of mycelium from twenty grams of soil sinks below two grams somewhere in the subsoil. This may not happen until the bottom layer of the profile is reached but generally occurs above it and may (exceptionally) begin at the very surface. The only exception to this in the thirty experiments giving a statistically significant positive response is the one carried out at Boulein in **1938** where all layers of the profile are very well supplied. There are, however, a further thirty experiments whose subsoils are also deficient by this criterion. It appears moreover that the fungus provides the more discriminating test because, if statistical significance is disregarded, and an increase of one-tenth of a kantar or more arbitrarily taken as real, then there will be forty-one additional experiments in which the fertiliser has had a beneficial action. Twenty-seven out of the further thirty experiments mentioned as having deficient subsoils are included in these additional forty-one, the average increase in yield in them being 0·22 of a kantar per feddan. For the remaining fourteen with their richer subsoils the mean effect is **0·16** of a kantar which is less than the average (0·18) for the experiments as a whole. There remain three experiments with subsoils deficient by the Aspergillus method where the response to superphosphate is negligibly small or slightly negative.

TABLE XII

Cotton Experiments

Grams mycelium per 20g. soil in Aspergillus niger test for four years of experiments 1935–1938 (119 experiments)

Depth of layer (cm).	Average of thirty experiments showing significant positive response	Average of fifty-seven experimentc in Delta showing no significant response	Average of thirty-two experiments in Upper Egypt showing no significant response
C.S.S.	2·93	3·24	3·62
0– 25	2·71	3·09	3·43
25– 50	2·19	2·62	2·86
50– 75	1·87	2·41	2·54
75–100	1·76	2·35	2·49

The average mycelium weights given in Table XII show that the surface layers as well as the subsoils of profiles giving a significant response are poorer in available phosphoric acid than the surface layers of profiles from experiments in the Delta showing no significant response; the difference is not so great as between the subsoils but is still considerable. The very significantly greater variability of the surface layers of perennial land in available phosphoric acid content as compared with their subsoils has already been commented on. The variability of the subsoils of the profiles from experiments giving a significant positive response to superphosphate will obviously be much lower even than the general run. They have in effect become separated out from the others because at least one subsoil layer has given a value of less than two grams of mycelium. If only one layer is involved it is generally the lowest and the range of values given by the bottom layers varies between 1·46 and 2·00 grams. The variability of the surface layers will however remain as great as before and if the exceptional experiment at Boulein in 1938 is neglected the range for the twenty-nine experiments showing statistically significant positive response is 1·65 to 4·13, or almost five times that shown by the bottom layers. In such profiles, where the subsoils have become uniformly low in available phosphoric acid, any association between the surface (0–25 cm.) and the bottom (75–100 cm) layers will have been largely lost and the content in available phosphoric acid can no longer, as in basin land, be described as a characteristic feature of the profile. It would therefore be quite impossible to determine whether a soil is deficient in available phosphoric acid (for cotton) merely by an examination of the surface layer, except of course in the rare cases where that surface layer itself has become deficient.

The fact that it is deficiency in subsurface layers which largely decides whether cotton will respond to superphosphate or not makes an examination of the results of the cotton experiments from the point of view of variety of interest. It may be supposed that the deeper-rooted varieties such as Sakel, Sakha 4, Malaki, Karnak and Giza 7 will respond more than the shallow-rooted ones such as Zagora and Ashmouni. Table XIII gives an analysis of the results of the cotton experiments from this point of view.

TABLE XIII

COTTON VARIETIES AND RESPONSE TO SUPERPHOSPHATE

1933–1946

Variety	Number of experiments	Number showing a significant positive reponse	Percentage giving significant response	Average yield effect in kantars per feddan
Sakel and Sakha 7 ...	19	7	—	0·37 (0·24 for 18)
Sakha 4	15	6	—	0·13
Giza 7	77	29	37·6	0·26
Giza 12	24	8	33·3	0·09
Karnak	70	17	24·3	0·20
Menoufi	22	5	22·7	0·17
Zagora...	38	6	15·7	0·13
Ashmouni	136	29	21·3	0·15

With the exception of Ashmouni the distribution of these varieties in time is very unequal so that results may not be really comparable. Karnak for example was grown only in the second half of the period and Giza 7 mainly in the first. Even in the case of Ashmouni, which always accounts for the cotton grown in Upper Egypt, it has been seen that response during the first part of the period was very small compared with that obtained during the second. The varieties that show greatest average response are Sakel, Giza 7 and Karnak which are deep-rooted varieties. The fifth of a kantar given on the average by Karnak would, with normal times and prices, be well worth consideration.

The cotton experiments have also been examined from the point of view of degree of response obtained after various crops. The figures in Table XIV show that there is very little in it.

TABLE XIV

RESPONSE OF COTTON TO SUPERPHOSPHATE FOLLOWING VARIOUS CROPS

Previous crop	Maize	Berseem	Rice
No. of experiments	206	94	65
No. responding significantly	59	25	18
Percentage showing significant response	28·6	26·5	27·6
Average yield effect in kantars per feddan	0·19	0·18	0·20

Wheat Experiments

Use is made in the wheat experiments of four levels of nitrogen (0, 1, 2 and 3 sacks of nitrogenous fertiliser, each sack supplying 15 1/2 kilograms of nitrogen) and two levels of phosphate (0 and 2 sacks of 16–18 per cent superphosphate) giving eight treatments, the layout being six randomised blocks with plot size 1/40th of a feddan. The superphosphate is broadcast before sowing and the nitrogen applied at the first watering which is given in December before the closing of the canals. The series was begun in the season 1935–1936 and is being continued. The average results by years and for the whole period of eleven years, eliminating season, are given in Table XV, the figures for the Delta and Upper Egypt being separately treated.

TABLE XV

Results of Wheat Experiments

Year	Number of Experiments	Number in Delta	No. positively signifiicant in Delta	Number in Upper Egypt	No. positively significant in Upper Egypt	Average direct Effect in ardebs per feddan		
						Delta	Upper Egypt	Overall
1935–36	24	17	5	7	1	0·23	-0·07	0·14
1936–37	27	19	6	8	3	0·30	0·21	0·27
1937–38	21	13	3	8	0	0·20	0·30	0·24
1938–39	24	15	7	9	3	0·35	0·66	0·47
1939–40	19	10	4	9	1	0·33	0·04	0·19
1940–41	23	15	3	8	3	0·20	0·25	0·21
1941–42	29	16	6	13	4	0·48	0·34	0·42
1942–43	28	14	5	14	3	0·32	0·17	0·24
1943–44	29	15	4	14	6	0·23	0·52	0·37
1944–45	30	14	4	16	6	0·31	0·33	0·32
1945–46	34	17	7	17	6	0·20	0·24	0·22
Totals and averages ...	288	165	54 or 23·7%	123	36 or 29·2%	0·29	0·27	0·28

The proportion of experiments giving a statistically significant positive response is roughly the same for Upper Egypt as for the Delta so that the average effect on yield in the two regions shows little difference.

Estimations of available phosphoric acid on soil samples from the 1935–1936 and 1936–1937 experiments have been made by the Aspergillus niger method. The results for individual profiles are given in tables in the appendix and the average of profiles from experiments showing significant response is compared with that for experiments not so responding in Table XVI.

TABLE XVI

Wheat Experiments

Grams mycelium per 20 g. soil in Aspergillus niger test for two years of experiments

Depth of layer (cm.)	Average of eleven experiments showing significant positive response	Average of thirty-one experiments showing a significant negative or no response
C.S.S.	2·97	3·40
0– 25...	2·74	3·21
25– 50...	2·17	2·67
50– 75...	1·91	2·53
75–100...	1·79	2·46

Forty-two experiments are reported on in the tables in the appendix. In the eleven in which a significant positive response to superphosphate was obtained the grams mycelium per twenty grams soil fall below two at least in the bottom layer of the profile and generally also in the layer or layers above it. Among the thirty-one profiles from the experiments giving no significant response are five in which the grams mycelium have also fallen below two in one or more layers. These five experiments do give some response but the extent is no greater than can happen where the profiles show no deficiency in available phosphoric acid.

The surface layers of the profiles (Table XVI) from experiments giving a significant response are also lower in available phosphoric acid than the surface layers of the experiments not responding. The difference is not so great as between their subsoils and it would again be impossible (as with the cotton experiments) except in the rare cases where these surface layers themselves have become exhausted to diagnose deficieney from the examination of the surface layers. The general picture for wheat is therefore very similar to that drawn for cotton except that it is more indefinite, perhaps because fewer experiments have been examined by the Aspergillus method, but more probably because (it will be demonstrated) the degree of response obtained is considerably dependant on the minimum temperatures experienced in the months of January and February.

The average benefit in yield from superphosphate of 0·28 of an ardeb would in normal times scarcely pay for the cost of the fertiliser necessary to occasion it. It should however be noted here that even if the average effect were considerably increased the nature of its distribution would have to be altered before manuring with superphosphate could become a general practice on wheat. This is apparent from the following considerations :—

Sixteen of the two hundred and eighty-eight experiments have given an increase of one ardeb or more from superphosphate. The total effect in the sixteen is 21·71 ardebs and averages 0·07 of an ardeb if spread over the whole two hundred and eighty-eight; in other words one-quarter of the average effect of 0·28 of an ardeb (Table XV) is contributed by one-eighteenth of the experiments. If increases of three-quarters of an ardeb or more are considered thirty-five experiments are found to be involved giving a total effect of 37·97 ardebs and averaging for the two hundred and eighty-eight 0·13 of an ardeb, *i.e.*, one experiment in eight accounts for something approaching half of the average effect of 0.28 on the whole. If the extent of response to superphosphate increases it might therefore become economically advantageous to define more precisely the (soil) conditions for success. As already mentioned above, the action of superphosphate on wheat takes place against a background of variable temperature which may have considerable influence.

Barley Experiments

The treatments and layout in the experiments with barley and maize are the same as for wheat. The average results obtained with barley are given in Table XVII.

TABLE XVII
Barley Experiments

Year	Number of Experiments	Number showing positive significant response	Average direct effect in ardebs per feddan
1935–36	17	2	0·16
1936–37	9	0	0·12
1937–38	5	0	0·20
1938–39	4	1	0·13
1939–40	7	1	0·26
1940–41	14	3	0·45
1941–42	14	4	0·31
1942–43	13	4	0·65
1943–44	19	6	0·70
1944–45	19	5	0·37
1945–46	27	10	0·55
Total and averages ...	148	36 or 24·3 per cent	0·36

Increases of one ardeb or more were obtained in twenty-six experiments, although in only twenty of these was the effect statistically significant. The total increase in these twenty-six amounted to 40·63 ardebs which, spread over the total of one hundred and forty-eight experiments, gives an average of 0·27 of an ardeb, i.e., the increase registered in twenty-six, or one in between five and six of the experiments, accounts for three-quarters of the total average increase of 0·36 of an ardeb.

No estimations of available phosphoric acid have been made in connection with the barley experiments.

Maize Experiments

The average results for these experiments are given in Table XVIII

TABLE XVIII

MAIZE EXPERIMENTS

Year	Number of Experiments	Number showing positive significant response	Average direct effect in ardebs per feddan
1934	13	2	0·15
1936	30	4	0·17
1937	26	2	0·08
1938	28	7	0·44
1939	26	6	0·29
1940	24	7	0·34
1941	33	4	0·09
1942	28	9	0·33
1943	26	7	0·21
1944	23	5	0·26
1945	13	2	0·14
1946	21	7	0·33
Totals and averages ...	291	62 or 21·3%	0·24

Nineteen experiments have given an increase of one ardeb or more per feddan giving 24·01 ardebs in all. That amount spread over the whole two hundred and ninety-one experiments means0.08 of an ardeb, i.e., nineteen experiments, or one in fifteen, are responsible for one-third of the total average increase of 0.24 of an ardeb.

Estimations of available phosphoric acid were made on samples taken from the six experiments giving a significant positive increase and a further eleven giving no significant response from the 1936 and 1937 experiments. The soils of the maize experiments are sampled to a depth of fifty centimetres only and it is seen that in all six of the experiments responding significantly the grams mycelium per twenty grams soil have sunk below two in this top fifty centimetres whereas in the soil samples from the experiments not so responding they have, with two exceptions, remained above that figure (see Table XIX).

TABLE XIX

Maize Experiments 1936 and 1937

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*a*) Experiments showing positive significant response: –

Locality	Saheli	Batra	Shebin el Kom	Konayessa	Qaha	Danasour
Yield effect from 2P in ardebs per feddan	0·69	1·35	0·40	1·48	0·77	1·07
Depth of layer (cm.)						
C.S.S.	2·33	4·33	4·13	2·65	4·97	2·20
0 –25	1·98	3·23	3·58	1·89	5·48	2·18
25–50	2·01	1·17	1·91	1·65	1·95	1·74

(*b*) Experiments showing no significant response;—

Locality	Monti	El Konaissa	Damanhour	Zawiet Mubarak	Kattawia
Yield effect from 2P in ardebs per feddan	+0·72	+0·50	+0·77	—0·39	—0·38
Depth of layer (cm.)					
C.S.S.	2·36	2·60	6·01	3·95	3·48
0 –25	2·13	2·43	5·88	3·63	3·01
25–50	1·74	1·80	5·83	3·10	2·95

Locality	Gimmeiza	Tarabamba	El Regalat	Qaliub	Taha el Bisha	Mataana
Yield effect from 2P in Ardebs per feddan	—0·19	+0·41	+0·21	—0·24	—0·13	—0·65
Depth of layer (cm.)						
C.S.S.	2·36	2·17	3·11	2·48	2·87	3·40
0–25	2·31	2·20	2·86	2·56	3·03	3·58
25–50	2·11	2·50	2·26	2·12	2·20	3·00

Temperature Effects

The purple bronze colour characteristic of phosphorus deficient berseem in cold winter weather has already been mentioned. The object here is to demonstrate that the kind and extent of yield effects from superphosphate are dependant in some measure on temperature, using results from the wheat crop mainly in illustration. The average figures for the effect of superphosphate on the yield of wheat grain in the experiments have been given in Table XV. In table XX the corresponding figures for the effect on straw yields have been set out. The average mean monthly minimum temperatures for the eleven years for December, January and February for three stations in the Delta are given in Table XXI and for two stations in Upper Egypt in Table XXII.

TABLE XX

WHEAT EXPERIMENTS

Effect of Superphosphate on Straw Yields[1]

Year	Number of Experi-ments	Number in Delta	Number positively significant in Delta	Number in Upper Egypt	Number positively significant in Upper Egypt	Average direct effect in himls [2] per feddan		
						Delta	Upper Egypt	Overall
1935-36 ...	24	17	6	7	1	0·49	0·11	0·38
1936-37 ...	27	19	5	8	5	0·52	0·50	0·51
1937-38 ...	21	13	5	8	1	0·61	0·19	0·45
1938-39 ...	24	15	8	9	4	0·58	0·67	0·62
1939-40 ...	19	10	6	9	3	0·23	0·58	0·41
1940-41 ...	23	15	3	8	3	0·05	0·18	0·10
1941-42 ...	28	16	7	12	6	0·50	0·50	0·46
1942-43 ...	28	14	5	14	5	0·31	0·28	0·30
1943-44 ...	28	14	6	14	9	0·32	0·46	0·39
1944-45 ...	30	14	3	16	8	0·51	0·40	0·45
1945-46 ...	34	17	6	17	6	0·21	0·34	0·28
Totals and averages[3]	286	164	60 or 36·5%	122	51 or 41·8%	0.40	0.38	0.39

(1) There are nine experiments in which there was a significant negative effect on the straw.

(2) One himl of straw = 250 kg.

(3) In two experiments the weights of straw were not recorded.

TABLE XXI

Average Mean Monthly Minimum Temperatures for Giza, Tanta and Zagazig (°C.)

Year	December	January	February
1935–36	7·1	6·5	7·7
1936–37	6·3	4·7	6·6
1937–38	7·8	6·2	5·8
1938–39	8·1	5·5	6·5
1939–40	8·1	5·5	6·7
1940–41	5·9	6·0	7·0
1941–42	7·4	4·4	6·5
1942–43	8·0	5·9	5·6
1943–44	10·3	6·6	6·6
1944–45	8·9	5·8	6·1
1945–46	6·8	6·9	6·4

TABLE XXII

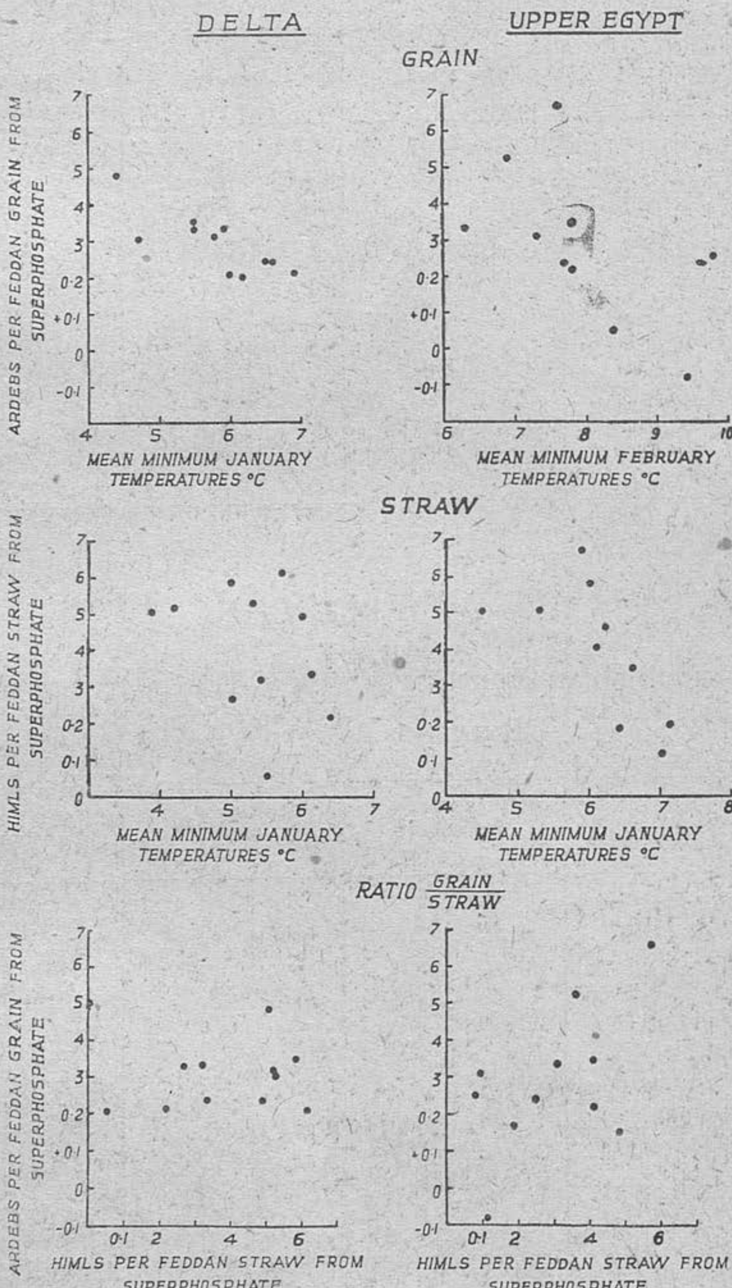
Average Mean Monthly Minimum Temperatures for Minia and Assiut (°C.)

Year	December	January	February
1935–36	7·2	7·0	9·4
1936–37	7·0	4·5	7·8
1937–38	8·1	7·1	7·3
1938–39	9·4	5·9	7·6
1939–40	8·7	6·0	8·4
1940–41	6·7	6·4	9·8
1941–42	7·4	5·3	7·8
1942–43	9·0	(1) —	—
1943–44	11·2	6·2	6·9
1944–45	9·1	6·1	6·3
1945–46	6·9	6·6	6·7

(1) Figures for Minia are not available for these two months.

FIG. 6 WHEAT EXPERIMENTS 1935-36 to 1945-46

RELATIONSHIP BETWEEN TEMPERATURE AND YIELD EFFECTS FROM SUPERPHOSPHATE



With the addition of two hundred kilograms of superphosphate the available phopshoric acid supply in the plots of the phosphate series in these experiments can be regarded as always being adequate and perhaps sometimes excessive. Experiments giving significant depressions in yield do not occur in every year and in some (colder) years even cases of non-significant negative effect may be few. The effects can however be regarded as ranging typically from positive significant increases through increases still positive but not significant to negative ones culminating exceptionally in significant depressions. The relative position taken up in the range by the individual experiment will presumably depend to a considerable extent on how well or how poorly supplied in available phosphoric acid the soil of the experiment was. The whole range will, however, shift to more positive or more negative values according to the nature of the season.

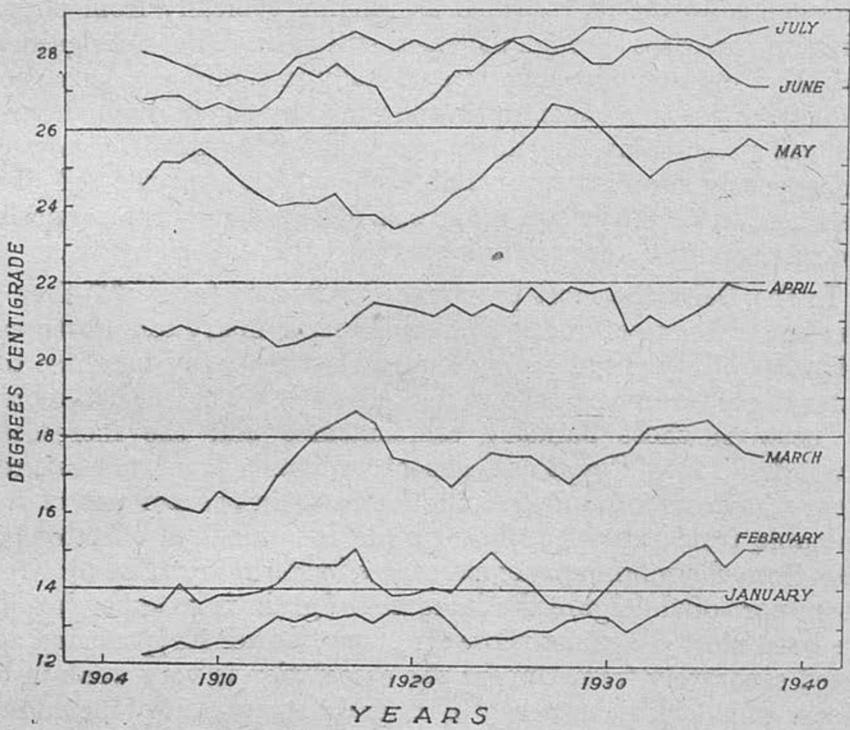
In the Delta the most pronounced influence ($r = -·75$) that can so far be demonstrated is that of minimum January temperatures on the increases in yield of grain ; the marked tendency for these to be greater in cold weather is shown in Figure 6(1). There is little connection between these January temperatures and the increases in straw. In Upper Egypt, on the other hand, low temperatures in January have mainly affected the increases in the amount of straw obtainable from superphosphate, while the principal effect on grain comes from the minimum temperatures in February (Fig. 6). In the bottom part of the figure the increases of grain from superphosphate have been plotted against those for straw, Lower Egypt being again treated separately from Upper ; the association is very weak in both regions. This lack of constancy in the grain-straw ratio of the increases is connected with the fact that in forty-nine of the experiments averaged in Table XX large, and significant increases in the straw have been recorded without a corresponding, or even much, effect on the grain ; the opposite does not occur so frequently but even so there are thirty-one experiments in which the grain yield alone was significantly affected.

The growth of straw is encouraged by warm weather and a plentiful nitrogen supply ; it is when the possibilities from nitrogen are restricted by cold that the positive influence of phosphoric acid increases. The climate of Upper Egypt, being on the whole warmer than that of the Delta, the growth of straw is in general greater there and may account for the difference in the emphasis of January and February minimum temperatures between the two regions. Positive effects from superphosphate will become reduced as conditions favouring the rapid growth of straw are increasingly realised and may eventually become negative in soils with excessive available phosphoric acid.

(1) There is a similar, but much weaker, association between minimum April temperatures and the response of cotton to superphosphate.

MEAN OF DAY TEMPERATURE (°C)
HELWAN 1904-1940
Five year running averages through monthly means

FIG. 7



Depressant effects of superphosphate under conditions favouring rapid vegetative growth can occur with other crops as well as wheat. They are illustrated below from an experiment with cotton at Kafr Hassan Saad in Qaliubia in 1938 (1) in which dibble-sowing was compared with ordinary sowing under varied conditions of nitrogen and superphosphate supply :—

		ON	1N	2N	3N	4N	Mean
0P	Dibble sowing	6·35	7·22	7·56	8·08	8·30	7·50
	Ordinary sowing	5·18	6·34	6·86	7·64	7·60	6·72
2P	Dibble sowing	6·24	6·37	7·32	7·62	6·98	6·91
	Ordinary sowing	5·25	7·45	7·15	7·68	7·81	7·07
	mean	5·76	6·85	7·22	7·76	7·67	7·05

S.E.=0·21.

The object of dibble-sowing is to have as many of the plants as possible in the best condition so that their growth performance will be superior; the consistent increase in yield from dibble-sowing with out superphosphate shows that this has been achieved. In the presence of superphosphate the advantage is maintained only so long as no nitrate is given; when dibble-sowing, nitrate and superphosphate are combined the advantage from dibbling is trivial or may actually be reversed.

Seasonal Variation in General

The range of yield effects from superphosphate on wheat grain arising from temperature variation may not seem large enough to be economically of any great moment. The experiments averaged in the table were however carried out in a period of high or rising temperature towards which there had been a long period change in the course of the thirty-seven years from 1904–1940. In Figure 7 are shown the five-year running averages through the monthly mean of day (true mean) temperatures at Helwan observatory for the first seven months of the year for the years 1904–1940. It is very probable that an opinion on the utility of superphosphate on wheat would be much more favourable were it based on the results of experiments carried out in a period of low January and February temperatures such as happened prior to 1914.

(1) "Dibble Sowing of Cotton, Method, Effects and Profits" by W.L. Balls and D.S. Gracie, Technical Bulletin No. 229, Ministry of Agriculture Egypt (1939).

SUMMARY

Land still under the basin system is taken to represent the original condition of land now under perennial irrigation.

Basin land is very well supplied with total phosphoric acid. This total phosphoric acid is on the average, the same in all layers and does not vary significantly with depth, a reflection of the fact that the amount present is a characteristic feature of the individual profile. In perennial land the total phosphoric acid decreases with depth so that the amount present at one metre is very significantly less than that contained at the surface. The amount present remains a characteristic feature of the individual profile, but to a lessened extent.

The total phosphoric acid is separated into the two categories of "available" and "residual" by estimation of the available by the Aspergillus niger method. The available phosphoric acid tends to be positively associated with the clay and negatively with the residual (basin land).

The decrease with depth in the total phosphoric acid in perennial land has been almost wholly at the expense of the available ; decrease in the residual is slight. Both categories are characteristic features of the profiles of basin land as is the residual in those of perennial. The subsoils of perennial land are progressing towards a state of uniform exhaustion in available phosphoric acid.

The available phosphoric acid in the surface layers of perennial land is being maintained to some extent by manures of which beladi manure has been the most important, followed by superphosphate. Allowing for these additions the drain away from four million feddans of perennial land is calculated to be of the order of thirty-seven thousand tons of phosphoric acid a year and the total loss to the soil to be much more.

The demand for superphosphate may therefore be expected to increase ; ground mineral phosphates are ineffective.

Berseem has the largest requirement in phosphoric acid of the common agricultural crops and has given the greatest response to superphosphate in field experiments. One hundred kilograms of the fertiliser has increased the yield on the average by 11·3 per cent equal to about 700 kg. of dry matter per feddan.

Beans and rice show a higher degree of response than cotton. wheat, barley or maize. The nature of the response with the two former is not straightforward in that the effect is decreased when the fertiliser is accompanied by an application of nitrogen. The response of rice is independent of the available phosphoric acid in the soil as estimated by the Aspergillus niger method.

Cotton and wheat may respond significantly to superphosphate where the yield of mycelium in the Aspergillus niger method sinks below 2 g. per 20 g. soil (equal to 30 mg. phosphoric aicd per cent) anywhere within the first metre. With the shallower-rooted maize crop this has to happen in the top 50 cm. so that this crop shows a smaller degree of response than wheat or cotton.

In addition to deficiency in the subsoil positive yield effects from superphosphate are shown to be greater in cold than in warm weather using the result of eleven years of the wheat experiments and minimum January and February temperatures in illustration. Depressant effects from superphosphate can occur where the nitrogen supply and temperature combined afford exceptionally favourable conditions for rapid vegetative growth.

ACKNOWLEDGEMENTS

The estimations of total phosphoric acid were made by Dr. Ahmed Sayed Ahmed Shalabi and Abdel Hamid Ibrahim Mustafa; those of calcium carbonate and clay content by Mohammed Kamal Mohammed, Zaki Sawiris and Abdel Ghani Mitkees.

The field experiments have been conducted since 1940 by the Field Experiments Section and before then by the Agronomic Section. In their analysis we have had the assistance of Mohamed El Kadi, Ahmed El Shabassi and Mohamed Abou el Fadl of the Chemical Section.

APPENDIX

OF

ANALYTICAL METHODS AND RESULTS

Determination of Total Phosphoric Acid

The total phosphoric acid is extracted from the soil by the method proposed by W. Mclean(1). Ten grams of air-dried soil which has passed a 1 mm. sieve are transferred to a 500 ml. Kjeldahl flask and 15 ml. concentrated H_2SO_4 and 15 ml. HNO_3 added. The flask is heated gently for about fifteen minutes with periodic shaking. The flame is then increased and the heating continued until the flask is filled with white fumes and all the organic matter destroyed. In some cases the addition of more HNO_3 is required. After cooling the contents of the Kjeldahl flask are diluted with water and poured into a beaker from which they are filtered into a 250 ml. graduated flask, the residue being well washed with hot water. On cooling the flask is made up to the mark and aliquot portions of 50 ml. pipetted out for the determination of phosphoric acid by the Lorenz method (2) The results obtained by this method of extraction have been shown to be in good agreement with those obtained by the HCl extraction method proposed by the Agricultural Education Association. (3) The figures for total phosphoric acid are given in Tables 4 and 5.

(1) W. McLean, "The Determination of Phosphorus in Soils", Jour. Agric., Sci., XXVI 331, (1936).

(2) C. S. Piper, "Soil and Plant Analysis". p. 150. The University of Adelaide, Adelaide, 1942.

(3) "The Hydrochloric Acid Extract of the Soil," Agricultural Progress, VIII, 134 (1931),

Estimation of Available Phosphoric Acid by the Aspergillus niger Method

The estimation [1] of available phosphoric acid is carried out in 100 ml. conical flasks of a reasonable uniformity so that the surface area offered to the growth of the mycelium is always about the same. Five grams of the soil to be examined are placed in a flask and 30 ml. of a nutrient solution having the following percentage composition added :

K_2SO_4 … … … … …	0·02	Cu	0·00015	in form of sulphates
NH_4NO_3 … … … …	0·36	Fe	0·0001	
$MgSO_4$ … … … … …	0·03	Zn	0·0001	
Sucrose … … … …	10·0			
Peptone … … … …	0·1			
Citric acid … … … …	2·0			

the only source of phosphoric acid being the five grams of the soil under investigation. Some drops of a suspension of conidia of the fungus are then added and the flask put into an incubator for four days at 30° C. At the end of that time the tough mat of mycelium is removed by means of forceps, washed in distilled water and dried overnight in the oven at 60° C. The following morning the temperature of the oven is gradually raised to 100° C. and the heating then continued for a further two hours, when the mycelium is cooled and weighed. The determination is made in quadruplicate, the four mats of mycelium being dried and weighed together on the same watch glass, so that the weights reported are grams mycelium per twenty grams soil. The Boas-Poschenrieder strain of Aspergillus niger is used.

(1) This technique is largely based on the following two papers :

DRYBURGH

"The Examination of Soils by Means of Aspergillus niger" by A.M.SMITH AND A.~~[illegible]~~, J.S.C.I. LIII, 250T, (1934).

" Further Studies on the Aspergillus niger Method of Examining Soils. " by A. M. SMITH J.S.C.I. LV, 217 T, (1936).

Influence of Calcium Carbonate.—Egyptian soils always contain calcium carbonate and the two per cent citric acid used in the nutrient solution, instead of the more usual one per cent, was designed to permit of the decomposition of the average amount of calcium carbonate present while maintaining suitable conditions for the successful growth of the fungus. The effect of the presence of varying amounts of calcium carbonate on the results has at the same time been investigated.

Seventeen soils with calcium carbonate content varying from 0·30 to 5·62 per cent were examined by the method in nutrient solutions containing 1·5, 2·0 and 2·5 per cent citric acid. The weights of mycelium so obtained are given in Table 2 together with the final pH values of the culture solutions. The soils have been arranged in the table in ascending order of carbonate content. The weights of mycelium increase with increasing concentration of acid, the difference in yield betweeen the 1·5 and 2·0 per cent solutions being always greater than that between the 2·0 and 2·5 per cent solutions. The difference between the first two concentrations becomes seriously large when the soil containing 2·48 per cent $CaCO3$ is reached and between the second two with the 5·62 per cent $CaCO3$ shown by the last sample in the table. Since soils containing as much as 5 per cent $CaCO3$ are rarely met with, the routine use of 2 per cent citric acid is the easiest course but it means that the final pH values can vary from 2·02 to 2·90 largely according to the calcium carbonate present.

As constant potential differences could not be obtained with the quinhydrone electrode the pH values were determined by the potentiometric titration of Britton and Robinson's (1) standard buffer solution using antimony electrodes. It was found necessary to keep the antimony brightly polished. The initial pH values of the nutrient solutions with the three concentrations of citric acid were the same at 2·63.

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(1) H. T. S. Britton. "Hydrogen Ions" (Chapman and Hall, 1932—2nd ed.).

Phosphoric Acid in Mycelium:—The mycelium weights, covering the range encountered, from nineteen soils were analysed for phosphoric acid with the results given in Table 3. The graph (Fig. 8) showing the relationship between weight of mycelium produced and phosphoric acid taken up is not a straight line since the percentage of phosphoric acid in the mycelium is not constant but varies from 0·26 to 0·72 per cent. This graph has been used to convert mycelium weights into terms of phosphoric acid where this has been desired.

The possibility that four days might be too short for the complete absorption of all the available phosphoric acid was investigated with seven samples with the following average result:—

TABLE 1

Period of incubation in days	Weights mycelium per 20g. soil	Per cent P_2O_5 in mycelium	Mg. P_2O_5 from 100g. soil
3	1·97	0·50	50·5
4	3·00	0·43	65·2
5	3·29	0·41	68·8
6	3·36	0·39	67·2

Absorption is practically complete after the four day period.

TABLE 2

INFLUENCE OF CALCIUM CARBONATE

Soil No.	Per cent $CaCO_3$	Per cent citric acid in culture solution	Grams mycelium per 20 g. soil	Ml. N/5 NaOH	Per cent neutra-lisation	Final pH values
31 C	0·30	1·5	1·74	2·50	10·0	2·20
		2·0	2·00 (1·99)	2·40	9·6	2·19
		2·5	2·28	2·35	9·4	2·18
3 D	0·59	1·5	2·10	2·35	9·4	2·14
		2·0	2·31 (2·24)	1·50	6·0	2·02
		2·5	2·47	1·70	6·8	2·06
1 D	0·60	1·5	1·92	2·80	11·2	2·28
		2·0	2·06 (1·96)	3·20	12·8	2·38
		2·5	2·18	3·60	14·4	2·52
27 C	1·18	1·5	1·79	3·45	13·8	2·46
		2·0	2·00 (1·77)	3·45	13·8	2·46
		2·5	2·12	3·45	13·8	2·46
7 B	1·50	1·5	1·94	3·85	15·4	2·60
		2·0	2·13 (1·97)	3·10	13·6	2·45
		2·5	2·21	3·65	14·6	2·54
27 C.S.S.	1·53	1·5	3·21	3·25	13·0	2·40
		2·0	3·46 (3·52)	3·20	12·8	2·39
		2·5	3·55	2·80	11·2	2·28
11 D	2·02	1·5	2·10	3·55	14·3	2·50
		2·0	2·31 (2·24)	3·65	14·7	2·54
		2·5	2·47	3·20	12·9	2·40
39 C.S.S.	2·22	1·5	3·24	3·45	13·8	2·45
		2·0	3·52 (3·31)	3·55	14·2	2·50
		2·5	3·62	3·50	14·0	2·48
20 C.S.S.	2·48	1·5	2·18	4·35	17·4	2·81
		2·0	2·65 (2·29)	3·95	15·8	2·65
		2·5	2·61	3·90	15·6	2·63
2 A	2·92	1·5	3·06	3·10	12·4	2·36
		2·0	3·45 (3·33)	3·25	13·0	2·40
		2·5	3·66	3·10	12·4	2·36

TABLE 2

Influence of Calcium Carbonate (*contd.*)

Soil No.	Per cent $CaCO_3$	Per cent citric acid in culture solution	Grams mycelium per 20 g. soil	Ml. N/5 NaOH	Per cent neutralisation	Final pH values
4 C.S.S.	3·76	1·5	2·49	4·65	18·6	2·92
		2·0	3·08(2·61)	4·50	18·0	2·88
		2·5	3·18	4·10	16·4	2·70
21 A	3·88	1·5	2·66	4·45	17·8	2·86
		2·0	3·31(2·88)	4·05	16·2	2·69
		2·5	3·41	4·05	16·2	2·69
17 A	3·92	1·5	3·41	4·25	17·0	2·77
		2·0	3·98(3·98)	4·20	16·8	2·75
		2·5	4·07	4·20	16·8	2·75
4 A	4·43	1·5	2·16	4·50	18·0	2·88
		2·0	2·80 (2·33)	3·85	15·4	2·60
		2·5	3·04	3·35	13·4	2·44
15 B	4·63	1·5	3·48	4·50	18·0	2·88
		2·0	4·33(4·91)	4·20	16·8	2·75
		2·5	4·51	4·20	16·8	2·75
15 A	4·98	1·5	3·19	4·75	19·0	2·96
		2·0	4·13(4·00)	4·55	18·2	2·90
		2·5	4·20	4·50	18·0	2·88
15 C.S.S.	5·62	1·5	1·84	5·30	21·2	3·20
		2·0	3·05(2·70)	4·50	18·0	2·88
		2·5	3·67	4·30	17·2	2·80

FIG. 8. RELATIONSHIP BETWEEN MYCELIUM WEIGHT AND PHOSPHORIC ACID ABSORBE[D]

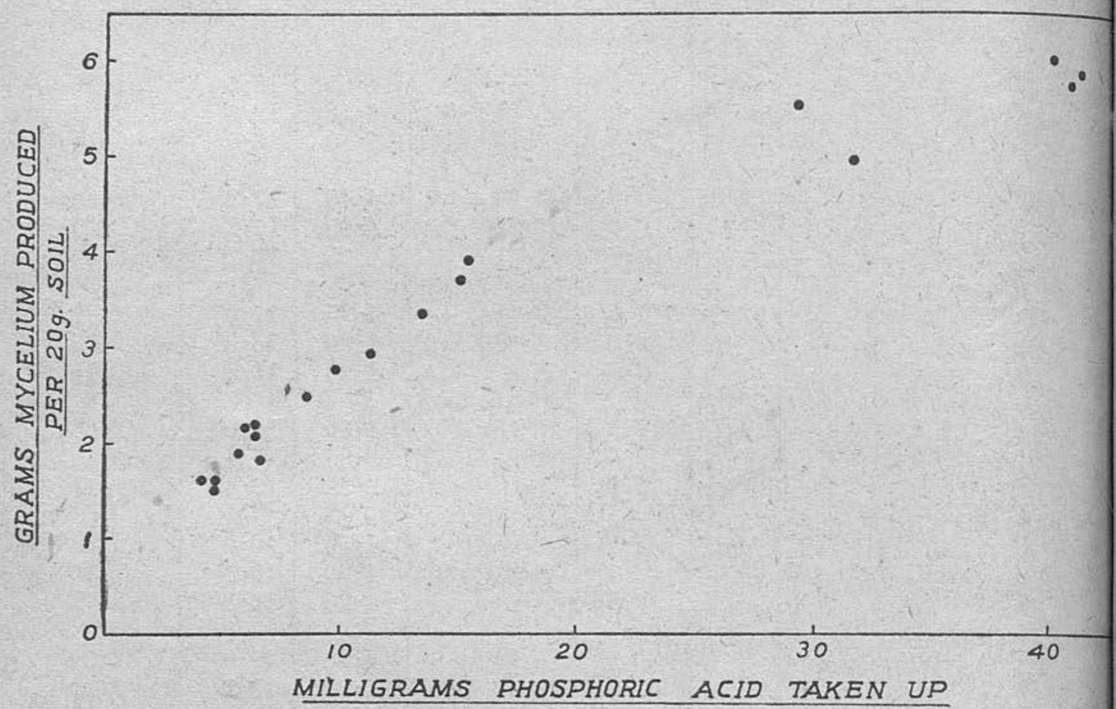

TABLE 3

Phosphoric Acid in Mycelium

Soil No.	Weight of mycelium from 20 g. soil	Per cent P_2O_5 in mycelium	Mg. P_2O_5 per 20g. soil
35 W 18 D	1·53	0·31	4·7
37 M 14 B	1·60	0·30	4·8
36 C 41 D	1·63	0·26	4·2
37 M 22 B	1·80	0·37	6·7
37 M 16 B	1·94	0·30	5·9
37 M 14 A	2·08	0·31	6·4
35 W 18 A	2·16	0·28	6·1
36 C 41 A	2·19	0·29	6·4
37 M 14 C.S.S.	2·50	0·34	8·6
37 M 12 B	2·77	0·36	9·9
37 M 12 A	2·95	0·38	11·3
37 M 12 C.S.S.	3·38	0·40	13·5
37 M 9 C.S.S.	3·73	0·40	15·1
37 M 9 C.S.S.	3·95	0·39	15·5
37 M 16 C.S.S.	4·97	0·64	31·7
37 M 16 A	5·56	0·53	29·3
37 M 8 C.S.S.	5·76	0·72	41·4
37 M 8 A	5·88	0·71	41·8
37 M 8 C.S.S.	6·01	0·67	40·3

TABLE 4

Basin Land Soils

Soil No.	Locality	Depth of layer cm.	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent	Clay content per cent
419	Harrania (Giza)	0 – 25	0·169	3·44	68	101	55·5
		25– 50	0·156	3·02	55	101	55·6
		50– 75	0·155	2·87	52	103	54·6
		75–100	0·145	2·53	43	102	55·1
533	Wasta (Beni-Suef)	0– 25	0·134	3·15	60	74	—
		25– 50	0·134	3·00	57	77	—
		50– 75	0·136	2·80	50	86	—
		75–100	0·155	2·80	50	105	—
		100–125	0·134	2·83	50	84	—
		125–150	0·155	2·90	52	83	—
534	Fashn (Minia)	0 – 25	0·136	2·33	39	97	56·7
		25– 50	0·119	2·31	38	81	56·8
		50– 75	0·070	2·26	38	32	56·9
		75–100	0·174	2·65	46	128	56·4
		100–125	0·067	2·70	47	20	57·8
		125–150	0·097	2·80	50	47	58·4
403	Samalut (Minia)	0 – 25	0·196	3·43	68	128	64·5
		25– 50	0·182	2·87	52	132	63·1
		50– 75	0·168	2·87	52	116	63·1
475	Hod el Milk (Assiut)	0 – 25	0·177	2·33	39	138	—
		25– 50	0·174	2·43	41	133	—
		50– 75	0·166	2·50	43	123	—
		75–100	0·179	2·70	48	131	—
		100–125	0·178	2·93	53	125	—
		125–150	0·177	3·00	55	122	—
476	Hod el Madwar (Assiut)	0 – 25	0·187	2·25	38	149	61·8
		25– 50	0·191	2·11	32	159	61·6
		50– 75	0·177	2·22	36	141	61·9
		75–100	0·191	2·22	37	154	61·7
		100–125	0·186	2·53	43	143	61·6
		125–150	0·189	2·43	41	148	60·7
561	Hod El Assi (Ass siut)	0 – 25	0·164	3·63	72	92	35·2
		25– 50	0·204	4·68	110	94	43·0
		50– 75	0·198	4·70	110	88	48·5
		75–100	0·198	4·00	85	113	48·6
		100–125	0·162	2·86	52	110	50·0
		125–150	0·181	3·00	55	126	49·7

TABLE 4

BASIN LAND SOILS (*contd.*)

Soil No.	Locality	Depth of layer cm.	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent	Clay content per cent
562	HodElGezira (Assuit)	0 – 25	0·215	3·18	62	153	40·1
		25– 50	0·178	2·03	30	148	39·9
		50– 75	0·193	1·80	26	167	35·0
		75–100	0·208	1·92	29	179	37·3
		100–125	0·206	2·13	32	174	41·7
		125–150	0·176	2·38	40	136	40·6
563	Hod El Zennar (Assiut)	0 – 25	0·224	3·08	58	166	66·5
		25– 50	0·225	3·08	58	167	68·0
		50– 75	0·224	3·10	59	165	67·5
		75–100	0·217	3·18	62	155	68·3
		100–125	0·221	3·01	55	166	68·5
564	Abnoub (Assiut)	0 – 25	0·222	3·32	64	158	46·8
		25– 50	0·209	2·27	37	172	44·6
		50– 75	0·204	2·28	38	166	55·0
		75–100	0·200	2·25	37	163	54·1
		100–125	0·217	2·13	32	185	48·2
565	Abnoub (Assiut)	0 – 25	0·207	2·80	50	157	38·7
		25– 50	0·201	2·12	32	169	39·6
		50– 75	0·199	2·12	32	167	35·5
		75–100	0·211	2·08	31	181	44·5
		100–125	0·202	2·25	37	165	56·1
385	Deirut (Assiut)	0 – 25	0·194	2·75	48	146	—
		25– 50	0·196	2·78	50	146	—
		50– 75	0·155	2·13	32	123	—
		75–100	0·146	1·95	30	116	—
535	Tahta (Girga)	0 – 25	0·222	2·83	50	172	54·2
		25– 50	0·186	1·90	29	157	27·9
		50– 75	0·191	2·12	33	158	32·2
		75–100	0·192	2·67	48	144	36·7
		100–125	0·183	2·80	50	133	34·6
		125–150	0·191	2·73	48	143	37·8
536	Sohag(Girga)	0 – 25	0·164	1·62	21	143	26·1
		25– 50	0·178	1·30	18	160	35·7
		50– 75	0·177	1·22	16	161	37·7
		75–100	0·180	1·33	18	162	39·2
		100–125	0·175	1·86	27	148	39·5
		125–150	0·182	2·12	33	149	47·2

TABLE 4

BASIN LAND SOILS (*contd.*)

No. Soil	Locality	Depth of layer (cm.)	Total P_2O_5 Per cent	Gm. mycelium from Aspergillus niger test.	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent	Clay content per cent
571	Hod Hashem (Girga)	0 – 25	0·211	2·33	39	172	36·6
		25– 50	0·204	2·39	40	164	29·8
		50– 75	0·190	2·52	43	147	20·3
		75–100	0·188	2·35	39	149	16·6
		100–125	0·205	2·48	42	163	30·8
		125–160	0·213	2·58	44	169	33·8
537	Samata (Qena)	0 – 35	0·212	2·97	55	157	56·2
		25– 50	0·212	2·84	51	161	55·7
		50– 75	0·220	3·00	55	165	54·9
		75–100	0·207	3·28	63	144	53·4
		100–125	0·227	3·46	68	159	49·5
		125–150	0·135	3·58	72	63	43·2
538	El Gabalaw (Qena)	0 – 25	0·216	2·95	54	162	54·3
		25– 50	0·212	2·86	51	161	53·9
		50– 75	0·224	3·05	58	166	54·0
		75–100	0·222	3·05	58	164	53·5
		100–125	0·212	3·35	65	147	53·6
		125–150	0·198	3·31	63	135	53·3
539	Tafnis (Qena)	0 – 25	0·191	3·35	64	127	55·8
		25– 50	0·232	3·43	67	165	55·7
		50– 75	0·182	3·50	70	112	56·0
		75–100	0·214	3·68	75	139	55·4
		100–125	0·204	3·80	77	127	52·4
		125–150	0·231	3·23	61	170	47·0
568	Qous (Qena)	0 – 25	0·286	4·60	106	180	49·0
		25– 50	0·305	4·66	107	198	49·6
		50– 75	0·289	4·77	115	174	49·0
		75–100	0·380	4·67	107	273	23·8
		100–125	0·253	4.00	85	168	20·6
		125–150	0·239	3.30	63	176	23·9
569	Qous (Qena)	0 – 25	0·282	4·85	118	164	—
		25– 50	0·277	4·91	120	157	—
		50– 75	0·272	5·10	130	142	—
		75–100	0·271	5·00	125	146	—
		100–125	0·223	3·53	70	153	—
		125–150	0·194	1·90	29	165	—

TABLE 5

Perennial Land Soils

No Soil.	Locality	Depth of layer (cm.)	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent
C 38	Gemmeiza	C.S.S.	0·216	2·90		
No. 1	(Gharbia)	0 – 25	0·199	2·81	50	149
		25– 50	0·170	2·75	47	123
		50– 75	0·165	2·52	43	122
		75–100	0·142	2·33	39	103
C 38	Sakha	C.S.S.	0·377	4·62		
No. 2	(Gharbia)	0 – 25	0·345	3·85	79	266
		25– 50	0·283	2·75	47	236
		50– 75	0·240	2·02	30	210
		75–100	0·225	1·83	27	198
C 37	Kasr el Gard	C.S.S.	0·167	2·40		
No. 19	(Gharbia)	0 – 25	0·170	2·10	31	139
		25– 50	0·165	1·66	23	142
		50– 75	0·168	1·64	23	145
		75–100	0·164	1·59	22	142
W 38–39	Tombara	C.S.S.	0·170	2·35		
No. 4	(Gharbia)	0 – 25	0·159	2·39	41	118
		25– 50	0·172	2·23	37	135
		50– 75	0·163	1·91	29	134
		75–100	0·150	1·83	27	123
C 38	Shotout	C.S.S.	0·152	5·20	—	—
No. 12	Demiat	0 –25	0·129	4·85	—	—
	(Daqahlia)	25– 50	0·147	4·73	—	—
		50– 75	0·128	5·05	—	—
W 35–36	El Baramoun	C.S.S.	0·193	2·20		
No. 18	(Daqahlia)	0 – 25	0·190	2·13	31	159
		25– 50	0·168	1·66	23	145
		50– 75	0·160	1·57	22	138
		75–100	0·159	1·50	21	138
W 38–39	Kom Beni	C.S.S.	0·167	2·33		
No. 15	Marass	0 – 25	0·182	2·35	39	143
	(Daqahlia)	25– 50	0·188	2·28	38	150
		50– 75	0·165	1·93	29	136
		75–100	0·163	1·88	28	135

TABLE 5

PERENNIAL LAND SOILS *(contd.)*

Soil No.	Locality	Depth of layer (cm.)	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent
W 38–39	Kom el Akhdar	C.S.S.	0·227	5·28	—	—
No. 13	(Behera)	0 – 25	0·207	4·75	—	—
		25– 50	0·204	4·80	—	—
		50– 75	0·200	4·22	—	—
C 38	Gabaris	C.S.S.	0·158	2·37		
No. 20	(Behera)	0 – 25	0·157	2·13	32	125
		25– 50	0·143	1·85	27	116
		50– 75	0·133	1·70	25	108
		75–100	0·138	1·80	26	112
W 35–36	Mit Gaber	C.S.S.	0·210	3·93		
No. 21	(Sharqia)	0– 25	0·176	3·28	63	113
		24– 50	0·152	2·36	39	113
		50– 75	0·144	2·30	38	106
		75–100	0·144	2·18	35	109
W 38–39	Mit Gaber	C.S.S.	0·210	3·25		
No. 17	(Sharqia)	0 – 25	0·175	3·10	58	117
		25– 50	0·159	2·83	50	109
		50– 75	0·163	2·74	47	116
		75–100	0·208	2·53	43	165
C 38	Goheina	C.S.S.	0·139	3·18		
No. 26	(Sharqia)	0 – 25	0·154	3·73	75	79
		25– 50	0·123	2·52	43	80
		50– 75	0·113	2·33	39	74
		75–100	0·102	2·42	40	62
W 38–39	Mehallet Subk	C.S.S.	0·219	3·85		
No. 10	(Menufia)	0 – 25	0·219	3·60	71	148
		25– 50	0·178	2·60	45	133
		50– 75	0·153	2·00	30	123
		75–100	0·159	1·83	27	132
C 39	El Hamoul	C.S.S.	0·253	4·13		
No. 16	(Menufia)	0 – 25	0·220	3·61	71	149
		25– 50	0·196	2·32	39	157
		50– 75	0·190	2·08	31	159
		75–100	0·178	1·87	28	150

TABLE 5

PERENNIAL LAND SOILS (*contd.*)

Soil No.	Locality	Depth of layer (cm.)	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent
C 37	Danasour	C.S.S.	0·201	4·21		
No. 33	(Menufia)	0 – 25	0·215	4·05	85	130
		25– 50	0·210	3·82	78	132
		50– 75	0·207	2·31	39	168
		75–100	0·207	1·87	28	179
C 37	Tablouha	C.S.S.	0·264	3·32		
No. 34	(Menufia)	0 – 25	0·251	4·13	88	163
		25– 50	0·214	1·75	25	189
		50– 75	0·201	1·79	26	175
		75–100	0·202	1·72	25	177
C 37	Mushtuhor	C,S.S.	0·282	5·86		
No. 26	(Qaliubia)	0 – 25	0·290	5·98	200	90
		25– 50	0·302	6·00	200	102
		50– 75	0·244	4·87	120	134
		75–100	0·211	3·82	77	135
C 37	Kafr Hassan	C.S.S.	0·176	2·95		
No. 25	Saad	0 – 25	0·164	2·65	46	118
	(Qaliubia)	25– 50	0·146	1·83	26	120
		50– 75	0·135	1·66	24	111
		75–100	0·130	1·82	26	104
W 38–39	Namoul	C.S.S.	0·151	2·70		
No. 20	(Qaliubia)	0 – 25	0·195	2·65	46	149
		25– 50	0·184	2·43	41	143
		50– 75	0·162	2·38	40	122
		75–100	0·161	2·31	38	123
C 37	Nazlet el Simanan	C.S.S.	0·149	—	—	—
No. 35	(Giza)	0 – 25	0·153	—	—	—
		25– 50	0·127	—	—	—
		50– 75	0·034	—	—	—
		75–100	0·020	—	—	—
W 38–39	El Tarfaya	C.S.S.	0·198	2·83		
No. 25	(Giza)	0 – 25	0·204	3·02	55	149
		25– 50	0·182	2·65	46	136
		50– 75	0·160	2·49	43	117
		75–100	0·149	2·33	38	111

TABLE 5

Perennial Land Soils (*contd.*)

Soil No.	Locality	Depth of layer (cm.)	Total P_2O_5 per cent	Gm. mycelium from Aspergillus niger test	Available P_2O_5 mg. per cent	Residual P_2O_5 mg. per cent
W 38–39 No. 41	Shater Zada (Beni Suef)	C.S.S.	0·201	3·60		
		0 – 25	0·208	3·75	75	133
		25– 50	0·201	2·97	55	146
		50– 75	0·201	2·08	31	170
		75–100	0·205	1·93	29	176
C 37 No. 39	Taha el Bisha (Beni Suef)	C.S.S.	0·218	2·61		
		0 – 25	0·207	2·58	45	162
		25– 50	0·187	2·43	41	146
		50– 75	0·185	2·36	40	145
		75–100	0·180	2·27	37	143
C 38 No. 43	Burgaya (Minia)	C.S.S.	0·210	4·11		
		0 – 25	0·217	3·68	73	144
		25– 50	0·183	3·01	55	128
		50– 75	0·175	2·02	30	145
		75–100	0·179	1·74	25	154
W 38-39 No. 9	Ninaiya (Minia)	C.S.S.	0·187	3·35		
		0 – 25	0·182	3·13	60	122
		25– 50	0·177	2·86	51	126
		50– 75	0·162	2·74	47	115
		75–100	0·163	2·62	45	118
C 38 No. 45	Mallawi (Assiut)	C.S.S.	0·242	4·17		
		0 – 25	0·250	4·38	97	153
		25– 50	0·196	3·28	64	132
		50– 75	0·186	2·77	48	138
		75–100	0·185	2·49	43	142

TABLE 6

Cotton Experiments, 1935

(Grams mycelium per 20g. in Aspergillus niger test)

(*a*) Experiments showing significant positive response:—

Locality	Shoqa	Siberbai	Gim-meiza	Ezbet el Wist	Zamzam	Oesh el Hagar	Kufur el Raml
Yield effect from 2P in kantars per feddan ...	0·25	0·60	0·63	0·30	0·25	0·29	0·25
Depth of layer (cm.)							
C.S.S.	2·56	2·30	1·70	2·20	3·28	3·00	3·54
0 – 25	2·31	2·15	1·65	2·05	2·46	2·86	2·66
25– 50	2·17	1·96	1·54	1·77	2·15	1·90	1·96
50– 75	2·05	1·88	1·50	1·81	1·85	1·30	1·76
75– 100	1·94	2·05	1·53	1·97	1·89	1·49	1·69

(*b*) Experiments showing no significant positive response :—

Locality	Sakha	Kafr el Sheikh	Motam-adiya	Miniet Ebiar	Itai el Baroud	Shubra Hore	Ghorour	El Ba-ramone
Yield effect from 2P in kantars per feddan ...	+0·01	—0·19	+0·37	—0·08	+0·53	—0·01	+0·24	+0·06
Depth of layer (cm)								
C.S.S.	2·73	2·86	2·62	3·31	3·04	3·59	2·68	3·00
0 – 25...	2·36	3·30	2·31	3·12	3·49	4·01	3·95	2·86
25– 50...	2·38	3·57	2·26	3·12	2·30	2·81	4·90	1·90
50– 75...	2·30	3·51	1·99	3·14	1·82	2·27	5·21	1·30
75–100...	2·20	3·46	2·10	2·77	1·64	2·12	5·45	1·49

Locality	Mit Gaber	Halawat	El Qattawia	Kafr Atalla	Qaha	Marg	Mataana	Mallawi	Taha el-Bisha
Yield effect from 2P in kantars per feddan ...	+0·26	+0·16	+0·34	+0·37	+0·19	+0·10	—0·00	—0·09	+0·09
Depth of layer (cm.)									
C.S.S.	2·94	2·55	2·28	2·67	3·63	3·40	3·28	3·66	2·83
0 – 25... ...	2·79	2.86	2·00	2·61	3·06	3·02	3·30	3·12	2·56
25– 50... ...	2·55	2·85	1·89	2·04	2·17	2·25	3·35	2·03	2·50
50– 75... ...	2·09	3·03	1·84	1·97	1·99	2·10	3·80	1·81	2·21
75–100... ...	1·92	4·31	1·90	1·76	1·90	2·10	4·04	1·90	2·05

TABLE 7

Cotton Experiments, 1936

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*a*) Experiments showing significant positive response :—

Locality	Difra	Kafr el Sheikh	Siber-bai	Zebei-da	Zawiet Naim	Dim-shalt	Bala-moun	Bara-mone	Dana-sour
Yield effect from 2P in kantars per feddan ...	0·45	0·33	0·40	0·50	0·58	0·43	0·30	0·67	0·40
Depth of layer (cm.)									
C.S.S.	2·22	1·80	2·13	2·43	3·91	2·19	2·80	3·63	2·90
0 – 25...	2·20	1·89	2·14	2·27	3·50	2·36	2·70	2·41	2·87
25– 50...	1·81	1·94	2·03	1·94	2·78	1·56	2·32	1·79	2·17
50– 75...	1·70	1·90	1·92	1·71	2·06	1·37	2·02	1·60	2·02
75–100...	1·70	1·89	1·85	1·54	1·73	1·53	1·72	1·63	1·97

(*b*) Experiments showing no significant positive response :—

Locality	Gim-meiza	Sakha	Motam-adiya	Siber-bai	Ebiar	Kordi	Miniet Ebiar	Qara-qis	Itai el Baroud
Yield effect from 2P in kantars per feddan ...	+0·25	+0·16	—0·26	—0·04	—0·14	+0·07	—0·16	+0·21	—0·14
Depth of layer (cm.)									
C.S.S.	2·75	2·92	2·69	4·85	2·63	2·45	3·83	3·44	3·04
0 – 25...	2·21	2·98	2·79	5·07	2·37	2·28	3·44	2·98	2·60
25– 50...	1·61	2·72	2·40	4·52	2·03	2·08	3·11	2·19	2·16
50– 75...	1·56	1·91	2·16	4·16	2·30	2·15	2·84	2·04	2·25
75–100...	1·57	1·90	2·03	2·58	2·44	2·15	2.86	1·90	2·27

TABLE 7

Cotton Experiments, 1936 (*contd.*)

Locality	Kasr el Gard	Halawat	Shersheima	Qattawia	Qaha	Mehallet Subk	Tala
Yield effect from 2P in kantars per feddan	+0·18	+0·21	+0·23	—0·46	+0·22	+0·16	—0·07
Depth of layer (cm.)							
C.S.S.	2·75	2·30	2·20	2·63	4·00	2·91	5·00
0 – 25	2·85	2·18	2·15	2·33	2·97	2·68	4·33
25– 50	2·96	2·03	2·12	2·90	1·98	2·26	2·86
50– 75	2·12	1·83	1·89	2·87	1·96	2·16	2·40
75–100	1·86	1·89	1·75	2·72	1·95	2·19	2·54

Locality	Nazlet el Batran	Tersa	Matania	Taha el Bisha	Hawaslia	Mallawi	Awlad Toq	Mataana
Yield effect from 2P in kantars per feddan ...	—0·13	+0·14	+0.10	+0.11	+0·21	+0·18	—0·15	—0·38
Depth of layer (cm.)								
C.S.S.	4·68	5·31	4·02	2·21	3·35	4·24	2·44	3·97
0– 25	4·05	4·88	3·82	2.29	3·15	3·52	2·57	4·21
25– 50	3·01	4·04	2·37	1·66	2·56	2·35	2 88	4·61
50– 75	3·13	2·35	1·89	1·68	2·24	2·02	2·88	3·94
75–100	2·50	2·20	1·80	1·79	2·44	1·77	2·92	3·96

TABLE 8

Cotton Experiments, 1937

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*a*) Experiments showing significant positive response:—

Locality	Kasr el Gard	Qaha	Danasour	Tablouha
Yield effect from 2P in kantars per feddan ...	0·28	0·48	0·61	0·36
Depth of layer (cm.)				
C.S.S.	2·40	3·61	4·21	3·32
0 – 25	2·10	3·57	4·05	4·13
25– 50	1·66	2·55	3·82	1·75
50– 75	1·64	1·77	2·31	1·79
75–100	1·59	1·70	1·87	1·72

(*b*) Experiments showing no significant positive response:—

Locality	Gimmeiza	Sakha	Kafr el Sheikh	Miniet Ebiar	Ebiar	Itial el Baroud	Riad Pasha	Bala-mone	Mit Gaber
Yield effect from 2P in kantars per feddan ...	0·00	+0·19	–0·05	+0·36	+0·05	+0·10	+0·15	+0·22	+0·02
Depth of layer (cm.)									
C.S.S.	2·43	4·10	5·76	3·60	2·96	4·65	3·54	3·96	2·66
0 – 25...	2·01	3·76	5·43	4·10	2·91	4·48	3·08	3·70	2·58
25– 50...	1·82	2·80	4·80	2·95	2·20	2·97	1·90	3·34	2·51
50– 75...	1·75	2·36	4·54	2·01	2·07	2·43	1·82	3·38	2·43
75–100...	1·98	2·40	3·66	1·86	2·05	2·17	1·77	3·71	2·32

TABLE 8

Cotton Experiments, 1937 *(contd.)*

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*b*) Experiments showing no significant positive response ;—

Locality	Kafr Hassan Saad	Moushtohor	Bahtim	Mehallet Subk	Shubra Zingi	Nazlet el Simman	Tersa	Matania
Yield effect from 2P in kantars per fed.	+0·25	+0·11	0·00	—0·22	+0·08	—0·49	+0·15	—0·24
Depth of layer (cm.)								
C.S.S.	2·95	5·86	4·25	3·11	3·85	6·00	4·55	4·11
0 – 25	2·65	5·98	4·88	2·70	3·13	6·01	5·28	3·23
25– 50	1·83	6·00	3·00	2·53	2·73	4·84	2·63	2·80
50– 75	1·66	4·87	2·73	2·41	2·48	2·20	2·51	3·02
75–100	1·82	3·82	2·41	2.33	2·37	2·11	2·44	3·22

Locality	Taha el Bisha	Bourgaya	Minia	Mallawi	Balsafora	Mataana	Sids
Yield effect from 2P in kantars per feddan	+0·09	+0·33	+0·05	+0·07	+0·19	+0·25	—0·12
Depth of layer (cm.)							
C.S.S.	2·61	2·78	3·91	3·35	4·24	3·68	3·35
0 – 25	2·58	2·63	2·85	2·83	3·48	3·73	3·56
25– 50	2·43	2·41	2·63	2·62	3·09	3·00	2·67
50– 75	2·36	2·02	2·52	2·50	2·86	2·61	2·39
75–100	2·27	1·87	2·37	2·34	2·67	2·93	2·42

TABLE 9

Cotton Experiments, 1938

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*a*) Experiments showing significant positive response:—

Locality	Kafr el Sheikh	Miniet Ebiar	Qarm-out el Bahw	Man-soura	Gaba-ris	Bou-lein	Dana-sour	Mehal-let Subkh	Na-moul	Minia
Yield effect from 2P in kantars per feddan ...	0·17	0·47	0·27	0·27	0·74	0·21	0·56	0·40	0·31	0·56
Depth of layer (cm.)										
C.S.S. ...	2·68	3·93	3·47	2·28	2·37	5.00	2·84	3·93	2·35	2·82
0 – 25 ...	2·53	3·23	3·23	2·23	2·13	4.95	2·53	2·95	2·23	3·08
25– 50 ...	2·22	2·43	2·65	2·20	1·85	4.80	2·00	2·28	1·75	2·11
50– 75 ...	1·92	1·87	1·98	1·81	1·70	3.90	1·71	1·90	1·78	1·64
75–100 ...	1·88	1·79	1·82	1·65	1·80	2.71	1·53	1·63	1·62	1·53

(*b*) Experiments showing no significant positive response:—

Locality	Gim-meiza	Sakha	Kordi	Ebiar	Kafr Soli-man	Kom Beni Marass	Zebei-da	Mit Gaber	Kafr Atalla	Bah-tim
Yield effect from 2P in kantars per feddan...	—0·17	+0·10	+0·07	+0.19	+0.12	+0.01	+0·17	+0·11	+0·10	—0·03
Depth of layer (cm.)										
C.S.S.	2·90	4·62	3·01	2·48	2·55	2·45	2·92	2·95	2·61	3·95
0 – 25	2·81	3·85	2·85	2·18	2·57	2·39	3·60	2·38	2·38	3·55
25– 50	2·75	2·75	2·83	2·02	1·86	2·39	2·00	1·83	1·80	2·55
50– 75	2·52	2·02	2·42	1·62	1·73	2·49	1·93	1·57	1·61	2·43
75–100	2·33	1·83	2·23	1·60	1·62	2·41	1·74	1·46	1·62	2·38

Locality	Kafr Hassan Saad	Ayat	Zat el Kom	Sids	Beni Ahmad	Bour-gaya	Rega-lat	Mal-lawi	ElMin-shat	Mata-ana	Mata-nia
Yield effect from 2P in kantars per feddan ...	—0·12	—0·03	+0·09	—0·12	—0·01	+0·25	0·00	—0·21	—0·12	—0·06	+0·12
Depth of layer (cm.)											
C.S.S.	2·71	3·30	4·16	2·50	3·12	4·11	3.17	4·17	3·10	3·15	3·35
0 – 25	2·68	3·68	4·30	2·58	3·05	3·68	3.01	4·38	3·03	2·86	3·57
25– 50	2·53	2·60	3·07	2·62	2·80	3·01	2.65	3·28	2·65	3·09	3·14
50– 75	2·41	2·47	2·60	2·44	2·95	2·02	2.73	2·77	2·52	3·33	2·62
75–100	2·26	2·43	2·59	2·31	3·13	1·74	2.45	2·49	2·43	3·24	2·36

TABLE 10

Wheat Experiments, 1935–1936

(Grams mycelium per 20g. soil in Aspergillus niger test)

(*a*) Experiments showing significant positive response :—

Locality	Mit Ghamr	El Baramone	Qaha	Hassania
Yeild effect from 2P in ardebs per feddan	0·88	0·92	0·60	0.83
Depth of layer (cm.)				
C.S.S.	2·63	2·20	3·15	3·92
0 – 25	2·25	2·13	2·93	3·78
25– 50	1·97	1·66	2·44	2·34
50– 75	1·85	1·57	1·93	1·97
75–100	1·73	1·50	1·85	1·88

(*b*) Experiments showing no significant positive response :—

Locality	Gimmeiza	Kafr el-Sheikh	Motamadiya	El Kordi	Mehallet Roh	Qasr el-Gard	Qaraqis
Yeild effect from 2P in ardebs per feddan...	– 0·18	+ 0·04	– 0·26	– 0·63	+ 0·16	– 0·43	+ 0·55
Depth of layer (cm.)							
C.S.S.	2·71	2·96	2.60	2·65	3·11	2·45	2·71
0 – 25...	2·76	2·91	2·93	2·78	2·91	2·23	2·41
25– 50...	2·19	2·39	3·31	2·16	2·42	2·31	2·24
50– 75...	2·20	2·35	2·92	2·12	2·10	2·90	2·20
75–100...	2·03	2·13	2·32	2·41	2·21	3·09	2·03

Locality	Itai el-Baroud	Mit Gaber	Shersheima	Shebin el Kom	Mehallet Subk	Abu Girg	Mallawi
Yield effect from 2P in ardebs per feddan	+ 0·25	+ 0·11	+ 0·02	+ 0·41	+ 0·31	– 0·06	– 0·43
Depth of layer (cm.)							
C.S.S.	4·00	3·93	3·03	4·81	3·10	4·86	4·25
0– 25	3·88	3·28	2·75	4·36	2·68	3·86	3·60
25– 50...	3·26	2·36	2·52	2·34	2·41	2·75	3·22
50– 75...	2·22	2·30	2·34	1·30	2·32	2·62	3·01
75-100...	1·84	2·18	2·20	1·30	2·27	2·48	2·96

TABLE 11

WHEAT EXPERIMENTS 1936–37

(Grams mycelium per 20 g. soil in Aspergillus niger test)

(*a*) Experiments showing significant positive response :—

Locality	Kafr el Sheikh	Kordi	Miniet Ebiar	Qarmout el Bahw	Abu el Shuquq	Shubra el Balad	Mallawi
Yield effect from 2P in kantars per feddan ...	1·14	0·11	0·32	0·71	0·48	0·64	0·77
Depth of layer (cm.)							
C.S.S.	3·55	2·94	3·32	2·78	2·31	2·41	3·60
0 – 25...	2·62	2·73	3·08	2·48	2·61	1·73	3·84
25– 50...	2·31	2·22	2·86	1·85	2·70	1·70	1·86
50– 75...	1·95	1·97	2·51	1·94	2·11	1·42	1·88
75–100...	1·87	1·89	1·95	1·86	1·92	1·50	1·80

(*b*) Experiments showing no significant positive response:—

Locality	Gim-meiza	Sakha	Mit el Fara-mawi	Bara-mone	Abu Sihma	Bou-lien	Dis-sounis	Mit Gaber	Qatta wia
Yield effect from 2P in kantars per feddan	+0·18	+0·51	+0·26	+0·27	—0·25	+0·38	+0·42	+0·08	+0·44
Depth of layer (cm.)									
C.S.S.	2·16	5·64	4·48	2·34	2·64	5·25	4·91	3·41	2·40
0 – 25...	1·91	5·29	4·45	2·17	3·00	5·24	5·14	2·75	2·11
25– 50...	1·49	4·51	4·06	2·11	2·31	4·53	2·79	2·40	2·20
50– 75...	1·75	4·66	5·23	2·08	2·41	3·75	2·15	2·27	2·09
75–100...	2·23	3·65	5·15	1·92	2·45	3·78	2·36	2·20	1·90

Locality	Qaha	Kafr Hassan Saad	Mit Khalaf	Batta	Matania	Sids	Qimn el Arous	Mata-ana
Yield effect from 2P in kantars per feddan...	+0·32	—0·14	+0·20	—0·20	—0·11	+0·15	+0·01	—0·05
Depth of layer (cm.)								
C.S.S.	2·60	4·47	2·42	2·25	3·51	3·20	2·27	4·28
0– 25	3·08	4·08	2·20	2·21	3·36	2·93	2·33	4·00
25– 50	3·14	2·90	2·21	2·32	2·35	2·22	2·35	3·14
50– 75	3·50	2·49	2·20	2·15	2·42	2·12	2·21	2·14
75–100	3·82	2·25	2·19	2·15	2·57	2·12	2·18	2·18

إن حامض الفسفوريك الصالح فى الطبقات السطحية من أراضى المشروعات يحتفظ بمقداره الى حد ما باضافة الأسمدة وأهمها السباخ البلدى و يليه سماد السوبرفسفات . ومع ادخال هذه الإضافات فى الحساب فان الفقد من أربعة ملايين من الأفدنة من أراضى المشروعات ، يقدر بنحو ٣٧٠٠٠ طن من حامض الفسفوريك سنويا ،وان ما تفقده التربة نهائيا يزيد عن ذلك المقدار بكثير .

بناء على ذلك ينتظر أن تزداد حاجة الأراضى المصرية لسماد السوبرفسفات . أما الفسفات المعدنية فانها عديمة الأثر .

أكثر المحاصيل حاجة لحامض الفسفوريك هو البرسيم فقد ظهر من التجارب الحقلية أنه أكثرها استجابة لسماد السوبرفسفات حيث بلغت الزيادة من مائة كيلوجرام من السماد ١١,٣٪ أو ما يوازى ٧٠٠ كيلوجراما من المادة الجافة للفدان .

وكانت درجة استجابة الفول والأرز للسماد أعلى من استجابة القطن أو القمح أو الشعير أو الذرة له . غير أن استجابة المحصولين الأولين لا تعتبر استجابة مستقيمة ذلك لأنها تتناقص اذا اقترنت اضافة سماد السوبرفسفات بالسماد الأزوتى ، وقد وجد أن استجابة الأرز للسوبرفسفات مستقلة عن مقدار حامض الفسفوريك الصالح المقدر بطريقة الأسبرجلس نيجر .

يستجيب كل من محصولى القطن والقمح استجابة واضحه للسوبرفسفات كلما نقص وزن الفطر فى طريقة الاسبرجلس نيجر عن جرامين لكل عشرين جراما من التربة فى أية طبقة من طبقاب التربة لغاية عمق متر (وهذا المقدار يوازى ٣٠ ملى جرام من حامض الفسفوريك فى المائة) أما فى حالة محصول الذرة السطحى الجذور فيجب أن يحصل هذا النقص فى الخمسين سنتيمترا العليا قبل أن يشاهد أثر إيجابى للسوبر فسفات وعلى ذلك تقل استجابة الذرة لهذا السماد عن استجابة القطن أو القمح له .

وعلاوة على نقص الفسفور فى الطبقات التحتية فقد أمكن اظهار أن أثر السوبرفسفات الإيجابى فى المحصول يزداد فى المواسم الباردة عنه فى المواسم الدافئة وقد تبين هذا من دراسة نتائج إحدى عشر عاما لتجارب القمح مع أدنى درجات الحرارة فى شهرى يناير وفبراير لتلك الأعوام — وقد يكون للسوبرفسفات أثر عكسى بخفض المحصول إذا كان مقدار الأزوت ودرجات الحرارة معا ملائمين للنمو الخضرى السريع .

ARABIC SUMMARY

الخلاصـــة

حامض الفسفوريك الكلى والصالح
فى الأراضى المصرية وأثر السوبرفسفات فى المحاصيل الرئيسية

تأليف

ديفيد . س . جريسى — بكالوريوس فى العلوم وزميل بالمعهد الكيميائى الملكى
فهمى خليـــل — بكالوريوس فى العلوم ودكتوراه فى الفلسفة

اعتبرت أراضى الحياض ممثلة للحالة الأصلية لأراضى المشروعات

إن أراضى الحياض غنية بحامض الفسفوريك الكلى ، ومقداره فى المتوسـط واحد فى جميع الطبقات ، وانه لا يتباين تباينا ظاهرا مع العمق ولذا فان المقدار الذى يوجد منه فى أية نقطة يعتبر مظهرا خاصا لذلك القطاع . أما فى أراضى المشروعات ، فان مقدار حامض الفسفوريك الكلى يتناقص مع العمق ، ولذا فان ما يوجد منه على عمق متر يقـل قلة واضحة عما يوجد منه بالطبقة السطحية، ويعتبر المقدار الموجود مظهرا خاصا بكل قطاع ولكن إلى درجة أقل مما هو الحال بقطاعات أراضى الحياض .

قسم حامض الفسفوريك الكلى إلى قسمين : "الصالح" و "البـاقى" وذلك بتقدير الجزء الصالح بطريقة الأسبرجيلس نيجر . ويلوح أن الجزء الصالح مرتبط بالطين ، ولا يوجد ارتباط بينه وبين المقدار "الباقى" (أراضى الحياض) .

كان جل التناقص مع العمق فى حامض الفسفوريك الكلى بأراضى المشروعات ؛ على حساب الجزء "الصالح" ذلك لأن التناقص قليل فى الجزء "الباقى" — ويعتبر كلا الجزئين مظهرا خاصا بقطاعات أراضى الحياض كما يعتبر الجزء "الباقى" مظهرا من مظاهر قطاعات أراضى المشروعات — وتتقدم الطبقات التحتية من أراضى المشروعات عموما نحو درجة موحدة من الافتقار فى الجزء "الصالح" من حامض الفسفوريك .

Printed at the Government Press,
Director-General,
HAMED KHADR.

Govt. Press 545-1948-550 ex.

MINISTRY OF AGRICULTURE, EGYPT

Technical and Scientific Service
Chemical and Agronomic Sections
Bulletin No. 152

An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt

[Continued]

BY

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GOVERNMENT PRESS, CAIRO, 1949

Government Publications are on sale at the "Sale Room", Ministry of Finance Correspondence relating to these publications should be addressed to the "Publications Office," Government Press, Bûlâq, Cairo.

Price - - - - - - - - - P.T. 25

CONTENTS

An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt (Continued)

Introductory

The unconventional nature of the response of cotton to nitrogenous manuring was pointed out in an analysis of the results of the first three years (1931–1933) of the manurial experiments with the crop [1]. It means that, in general, large returns from fertiliser nitrogen can only be expected where a high level of yield already exists. It is in direct contrast, for example, to the response of the maize crop; low-yielding land under maize tends to respond more than land which is already high yielding. The main conclusion drawn from the analysis was that the only practical steps that could be taken to increase the efficiency of nitrogenous fertilisers on cotton must be directed towards raising the general yield level.

Benefit from fertiliser nitrogen depends partly on its effect in increasing the number of early bolls and partly on the extent to which it is possible to pick the late bolls formed as the result of its use. In the account of the first three years of the experiments the fate of the latter was shown to depend on the temperatures experienced in July and August but the possibilities as regards the former were not fully recognised owing to the insufficient variety of season encountered. It was not unti 1936 and 1937 that it was possible to demonstrate the advantage that could be taken in the Delta of favourable spring temperatures such as then happened to increase the number of early bolls on early sown cotton; and not until the experiments had been running for eight years that the much more limited possibilities of a cold spring (1938) were fully realised [2]. It will also be demonstrated later that, owing to t e existence of long term se sonal variation, even the sixteen years (1931–1946) covered in the present account are not

(1) *"An Analysis of the Factors Governing the Response to Manuring of Cotton in Egypt"*, by David S. Gracie, Fahmy Khalil and Hussein Enan. Bulletin No. 152, Technical and Scientific Service, Ministry of Agriculture, Egypt (1935).

(2) *"Les Effets du Sol, de la saison et de la fumure sur la végetation et le rendement du cotonnier."* Bul. de l'Union des Agriculteurs d'Egypte, Mars 1939, No. 301 (D.S.G.).

"The Organic Content of Soils of the Middle East", by David S. Gracie. Proceedings of the Conference on Middle East Agricultural Development, p. 107 (1944).

necessarily representative of what may happen in the future. The degree of heat they encounter in August and late July continues to be a controlling factor in the fate of the late-formed bolls but the Delta summers of 1931 and 1933 remain respectively the worst and the best of the sixteen under review.

Recognition of the importance of spring temperatures in deciding the possibilities of increasing the number of early bolls has naturally led to the results for Upper Egypt (*i.e.* Egypt South of Cairo) being dealt with separately from those for the Delta. In the warmer climate of Upper Egypt some stimulation of early boll production by nitrogen is generally possible whereas favourable weather in the Delta does not occur every year. The most fundamental generalisation that can be made from the experiments in both regions is still to be found in the statement that the higher the level of yield without fertiliser nitrogen the greater will be the return from its use, the relationship being less pronounced in Upper Egypt than in the more exacting conditions of the Delta.

Discussion centres largely round variation in temperature and the essential background to it will be found in the two chapters on Development and Environment in "The Cotton Plant in Egypt" (1). Mean monthly maximum temperatures have been employed throughout for convenience as they give a better range, and soil temperatures are important, but it is of course actually minimum night temperatures that control the growth rate during the first half of the growing season. The optimum temperature for growth is about 32°C ; tissue temperatures which exceed 38° C. reduce the subsequent growth of the cotton plant to a marked extent, while prolonged exposures above 35° C. are proportionately harmful " (W.L.B.).

The main conclusion that Dr. Balls drew from his observations was that : " The author's colleague, Mr. F. Hughes, has shown conclusively that the cotton crop of latter-day Egypt is rarely limited—in Blackman's (2) sense—by the chemical composition of the soil. Water, always sufficient, but never excessive, is the principal need of the crop. " Level of yield is an expression of the physiologically available water.

Method of Experimention

The leading idea behind the field experiments is that for each year, they should be sufficiently numerous and well distributed throughout the country for the results to be capable of statistical analysis and to be representative of cotton-growing in Egypt as it actually is.

---

(1) W. L. Balls, "*The Cotton Plant in Egypt*" (MacMillan & Co., 1912).
(2) F. F. Blackman.

The variation due to soil, season and climate is such that isolated observations may be very misleading and can have little value; as much, if not more, emphasis is laid on the actual number of observations and on the length of time during which they are continued as on the accuracy of the individual experiment. The last has, however, in no way been neglected. The standard experiment from 1933 onwards has employed five levels of nitrogen (0, 1, 2, 3 and 4 hundred kilos of nitrogenous fertiliser [1] per feddan, each hundred kilos supplying 15½ kilos of nitrogen) and two levels of superphosphate (0 and 200 kilos of the 16–18 per cent fertiliser per feddan), giving in all ten treatments. The layout is in the form of six randomised blocks with plot size one-fortieth of a feddan so that the results can be treated by the analysis of variance [2]. The superphosphate is fassed into the south side of the ridge before sowing so as to be as near the seed as possible and the two smaller dressings of nitrogen given at thinning [3] which takes place roughly a month and a half after sowing; the two larger nitrogen dressings are split, two hundred kilos being given at thinning and the remainder at the next watering. The fertiliser is applied *takbish* i.e. in pinches just below the foot of the plants. The seed cotton harvested from the plots is weighed in rotls and the weights converted into kantars per feddan [4] at the rate of 315 rotls a kantar.

The manurial treatments apart, the instructions given are that there should be no alteration in the practice of the farms on which the experiments are carried out but that the details of that practice concerning sowing and picking dates, spacing, waterings, variety and previous crop should be recorded. The soil and climatic factors will vary from experiment to experiment and the seasonal one from year to year. Pink bollworm is unavoidable but the few experiments in which the cotton has been damaged by the cotton leaf worm have been rejected. From 1935 onwards the soils of the experiments have been sampled by taking a composite surface sample from the control plots and by sampling four successive layers of twenty-five centimetres each from

(1) From numerous trials carried out on the point it makes no *immediate* difference whether the nitrogen is supplied in the form of nitrate of soda, calcium nitrate, nitrochalk, sulphate of ammonia etc.,—the only nitrogenous fertiliser in which the nitrogen is slightly less efficient than the others is cynamide.

(2) R. A. Fisher and J. Wishart: "*The Arrangement of Field Experiments and the Statistical Reduction of the Results*". Imperial Bureau of Soil Science, Technical Communication No. 10 (1930).

(3) The question of time of application is raised again later as the result of the observations made on the available soil nitrogen (*see* p. 43).

(4) A feddan = 1·038 acres = 4,200 sq. metres.

A kantar of seed cotton = 315 rotls.

A kantar of cotton lint = 100 rotls = 99 lb. approx. = 44·928 kg.

a hole dug to the depth of a metre just off the edge of the experiment. These soil san ples are examined in the laboratory for available nitrogen and phosphoric acid and the results will be compared w.th the recorded yields.

The number of experiments is roughly thirty a year and the total carried out during the sixteen years from 1931 to 1946 is 491. The distribution of the 1936 experiments is shown in Fig 1 and may be regarded as typical, while the fact that the results taken as a whole are a reasonable reflexion of what happens in ordinary cultivation is demonstrated by Figs *2a* and *2b* where the average control plot yields plus the average increases obtained at 3N of Table 1 are compared with the average yields for all Egypt for each year of the experiments. The departure from the line of equality in Fig *2b* increases as the yields become higher; the amount of nitrogen (3N) used in the experiments is larger than for all Egypt and its efficiency will increase as the level of yield rises.

Error and Choice of Land

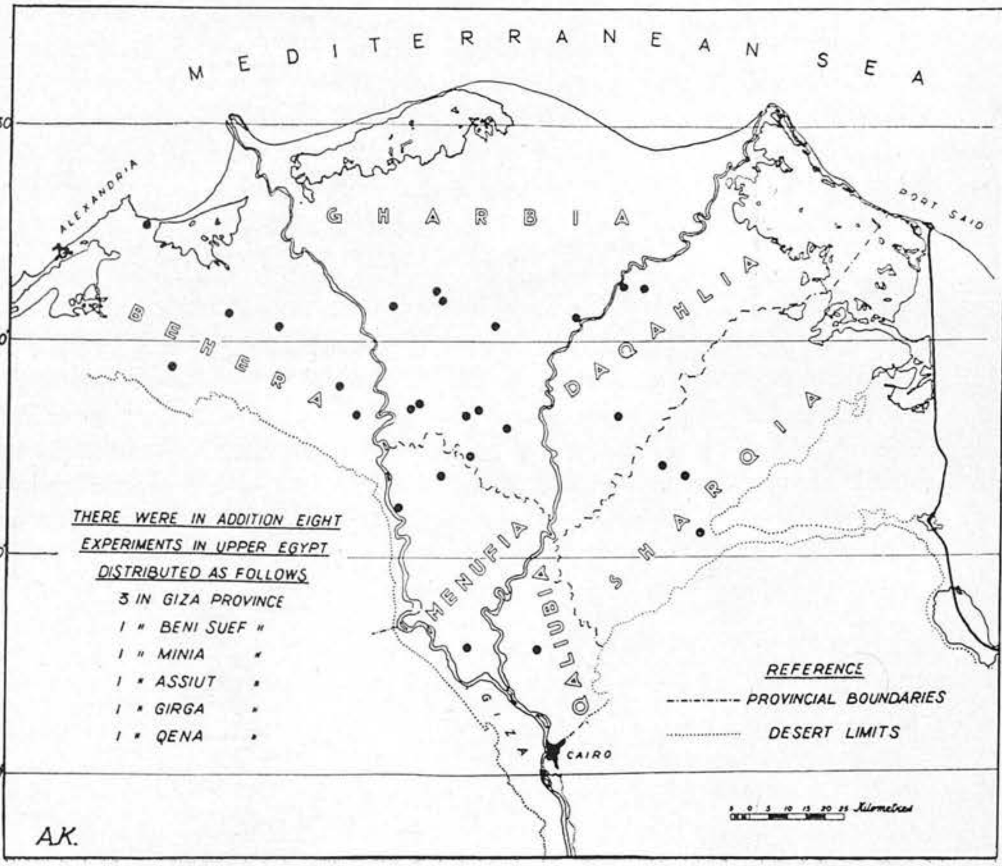
Fig. *2a* shows that the average yield in the experiments, while varying in a manner parallel to the average for the country, runs at a much higher level. This is partly because the yields are for net areas and partly because more nitrogen is used in the experiments but also because the choice of land is necessarily made with bias towards the good The variablity of Fgy, tian soi's is ɿ atura 'y co siderable but wl e e land is poor or has deteriorated it is much increased. Deteriorated land, having a lowered yield level, will at the same time give a lessened response to nitrogen and if the land is poor enough the random error may become so high that the treatment effects will be insignificant and the only conclusion that can be drawn is that the land is in fact poor. In view of this it is not surprising to find that there is a tendency for high standard error to be associated with low response to manure. The relationship was most pronounced in the 1939 experiments (Fig. 3) but in some years is little in evidence. The fact that it can exist is regarded as justifying the straightforward averaging of the results.

The Nature of the Effect of Treatments

As early a rise and as high a maximum of the flowering and bolling curves as possible are desirable since there must always be a large element of speculation about late-formed bolls — quite apart that is from the certainty of their being attacked by the pink bollworm. The main source of information available for the measurement of the

DISTRIBUTION OF THE 1936 COTTON MANURIAL EXPERIMENTS IN THE DELTA (27 EXPTS)

FIG. I



effect of treatments is the fact that the crop has generally been gathered in two pickings which have been separately weighed and recorded so that any alterations caused by manuring in the proportion of the crop obtained at the second picking can be followed. Where the effect of a treatment (*e.g.* an application of nitrogen) is to cause an increase or amplification of the initial rise in the flowering and bolling curves, the proportion of the crop at the second picking will remain the same or even diminish. On the other hand where the same application of nitrogen in another experiment results in a deformation or prolongation of the flowering and bolling curves, owing to the increased vegetative growth the proportion of the crop obtained at the second picking will increase to a greater or less extent, irrespective of whether the total yield is increased or not. In this latter case, although the total positive effect experienced in the yield may be considerable the nature of the reaction must be sharply distinguished from the former and the nitrogen or other factor causing it cannot be regarded as a limiting one in the same sense. Irrigation practice, spacing and sowing date are limiting factors in this sense since their proper adjustment is important in early boll production and therefore in determining the level of yield.

It should be clearly realised that nitrogen can be taken up without there being any corresponding increase in yield. The fact for example that the main effect of nitrogen can be to increase the proportion of the crop at the second picking without affecting the total yield is well illustrated by the extreme case of an experiment carried out at Gimmeiza in 1934 with Giza 7 cotton sown on the 6th of March after single cut berseem (berseem fahl). The picking dates were on the 28th of August and the 15th of September, which is fairly early:

EXPERIMENT WITH GIZA 7 AT GIMMEIZA IN 1934

Treatments	0N	1N	2N	3N	4N	S.E.
Yield in Kantars per Feddan	5·21	5·26	5·29	5·22	5·06	0·28
Proportions of the Crop at the Second Picking	50·7	59·6	62·4	66·8	71·1	1·8

Nitrogen was without significant effect on yield but very significantly increased the proportion of the crop at the second picking. As an interval of sixty three days was allowed to elapse between the sowing and the first waterings the result is perhaps not surprising.

Irrigation Practice

The practice of allowing cotton to go for six to eight weeks or longer without water after the sowing-watering belongs to the longer growing period of thirty-five years ago before the advent of the pink-bollworm. Such a long period without water subjects the plant to water strain and causes the loss, by shedding, of the early buds, i.e. the very ones which, under present conditions, ought to be preserved. It has been shown that this practice is definitely harmful and that it is now necessary to give the first watering three weeks after sowing and an extra heavy watering towards the end of June [1].

The results of fourteen watering experiments (two of them being in Upper Egypt) carried out in the three years 1931-1933, were reported in the previous publication on the manurial experiments. In addition to the normal practice of the district the treatments in them included watering rotations every twelve, fifteen and eighteen days in combination with first waterings after twenty-one and thirty days. Six of the fourteen gave a significant result in favour of more frequent watering; and of these six, five gave an indication of additional benefit from a first watering after twenty-one days.

Further information has been obtained almost as a side issue from the manurial experiments themselves. Unusually large returns from fertiliser nitrogen were obtainable in the Delta in 1936 and 1937 when it also happened that for the first time, with negligible exceptions, all of the cotton in the experiments was dibble-sown. As it was possible that this desirable result was due to the method of sowing having raised the yield level, the 1938, 1939 and 1940 experiments were altered to allow of a direct comparison of the effect of nitrogen on dibble-sown cotton as compared with cotton sown in the ordinary way. (It will be demonstrated later that the former can utilise nitrogen more efficiently than the latter but the very large returns possible from manure in the Delta in 1936 and 1937 will be shown to have depended mainly on the extent to which advantage was taken of exceptionally favourable March temperatures to sow early.) Direct effects from the dibble ranged from significant increases to significant depressions and provided a very confusing result until the increase or decrease in yield from dibble-sowing was set against both the interval (in days) between the sowing and the first waterings and the total interval between the sowing and the second waterings. The information so obtained is summarised below and illustrated in Fig 4 :—

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(1) J. Templeton, "*Watering and Spacing Experiments with Egyptian Cotton*". Technical Bulletin No. 112, Ministry of Agriculture, Egypt (1932).

Fig. 2a

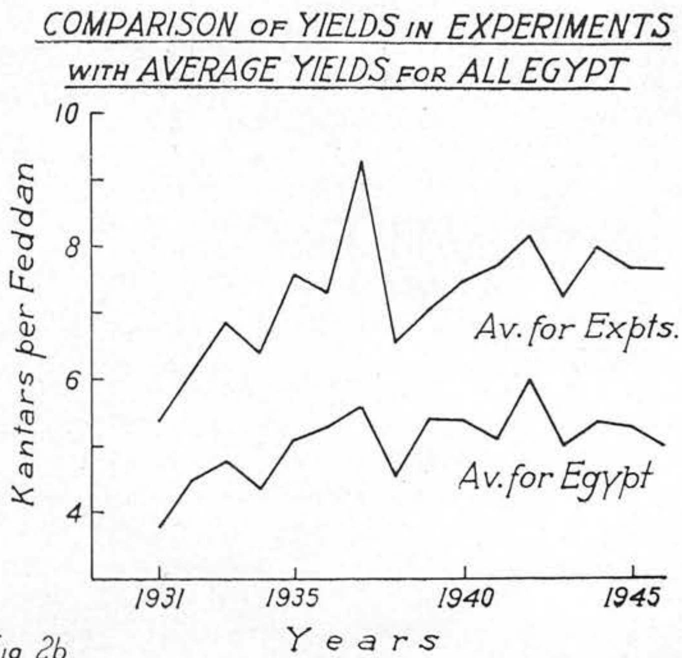
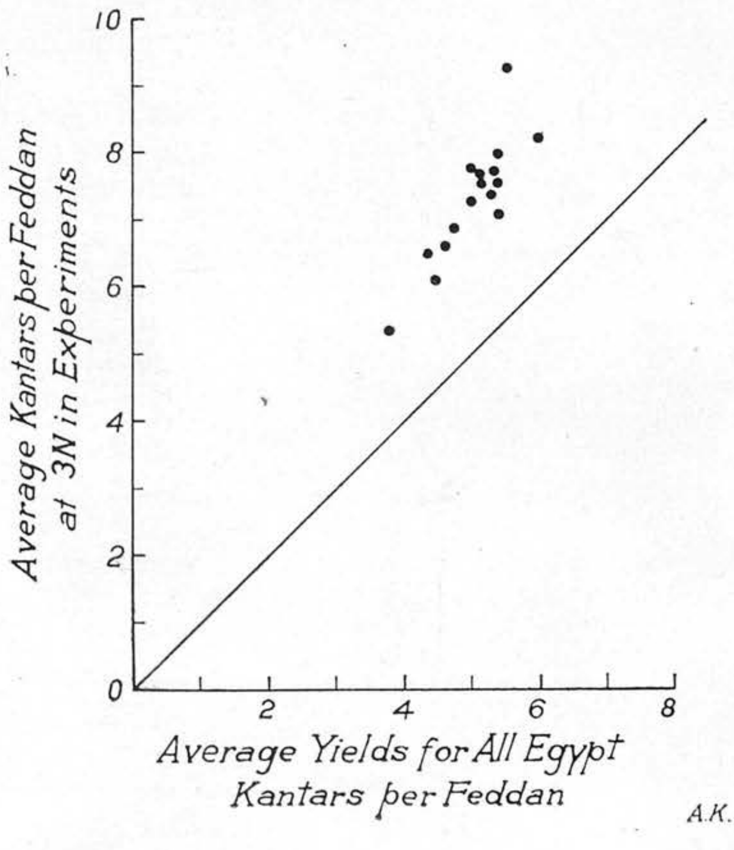

COMPARISON OF YIELDS IN EXPERIMENTS
WITH AVERAGE YIELDS FOR ALL EGYPT
10
8
6
4
Kantars per Feddan
Av. for Expts.
Av. for Egypt
1931
1935
1940
1945
Years

Fig 2b


10
8
6
4
2
0
Average Kantars per Feddan
at 3N in Experiments
2
4
6
8
Average Yields for All Egypt
Kantars per Feddan
A.K.

DIBBLE-SOWING AND WATERING INTERVALS

Year	Average interval in days between:				Correlation coefficients between yield effects from dibble sowing and :—	
	Sowing and first waterings	Range	First and second waterings	Range	Days between sowing and first waterings	Days between sowing and second waterings
1938	26·7	18–52	25·8	11–46	–·66	–·75
1939	30·5	15–47	21·9	11–36	–·19	–·27
1940	23·0	18–57	21·5	12–39	–·25	–·14

If dibble-sowing is practised it therefore becomes of increased importance that the better plants resulting should not be subjected to water strain. This was particularly so in 1938 when the growing season was very much colder than in the other two years and any adverse soil condition would have a disproportionately greater effect.

The " practice of the farm " in the Delta during 1934-1946 in the experiments in which it was recorded, is summarised below for the first part of the growing season :—

IRRIGATION PRACTICE IN THE DELTA COTTON EXPERIMENTS
1934–1946

Year	Average number of days between:			Number of experiments	Number of experiments with a first period > 40 days	Total number of experiments in Delta
	The sowing and first waterings	The first and second waterings	Total number of days			
1934	36·0	25·8	61·8	18	7	18
1935	30·3	27·5	57·8	16	2	21
1936	28·4	21·3	49·7	25	4	27
1937	27·5	27·1	54·6	18	3	20
1938	27·6	27·2	54·8	18	3	21
1939	31·5	22·8	54·3	16	6	16
1940	30·1	25·9	56·0	20	2	22
1941	31·5	24·2	55·7	19	4	21
1942	36·9	25·4	62·3	15	7	15
1943	36·6	26·7	63·3	19	8	20
1944	29·5	29·8	59·3	16	4	16
1945	27·5	29·5	57·0	19	1	20
1946	30·0	29·8	59·8	20	5	21
	TOTALS			239	56	258

In fifty-six of the experiments in the Table, being from a quarter to a fifth of the number in which the irrigation practice was recorded, the cotton was allowed to go for forty days or more without water after the sowing watering, the four years 1934, 1939, 1942 and 1943 accounting for half the number. Moreover the figures show a tendency for the second interval to be shorter where the first interval has been long which is itself a criticism of the practice of allowing too long a period to elapse between the sowing and first watering. Irrigation turns after the period dealt with in the Table are determined by the rotations in the canals, water being given at shorter intervals in Upper than in Lower Egypt.

Soil Factors Limiting the Level of Yield

No hard and fast rule can be laid down about irrigation practice since soils must be treated according to their individual requirements, but it is essential that the question be approached as much from the point of view of rate of renewal as from that of the total quantities of water given.

The physical properties of the soil with deep-rooted plants such as cotton dominate the situation because they decide not only the size of the roat system possible in the first place but also the amount of water available to the roots once these are established. If a soil for any reason is defectively aerated, *i.e.* if it is or has been poorly drained and has deteriorated, root penetration will be limited owing to lack of oxygen. Under such conditions it will also be found that, although the total quantity of water held by the soil may in itself seem adequate, yet the proportion of that water which is available to roots is unduly low. That is to say, that once a root hair has removed some water from its immediate neighbourhood the rate of renewal from the surrounding mass of soil is too slow to allow of an adequate supply to the plant; the competition of the soil itself for the water present may be regarded as being too strong compared with that of the plant. A the opposite extreme one may take the rare case of a well drained but very sandy soil, *i.e.* excellent conditions of aeration but where, although the rate of movement of water will be good, the total quantity of it available will, on the whole, be small. At the beginning of the season root penetration under these conditions will be extremely easy, the plant will rapidly achieve an extensive root system and vegetatively will tend to overgrow. When the increased strain on the aerial parts of the plant comes with the hot weather of summer, however, the limited total amount of water available for the enlarged vegetative growth shows itself in excessive shedding and a varying portion of the crop will be lost. The growth

Fig: 3

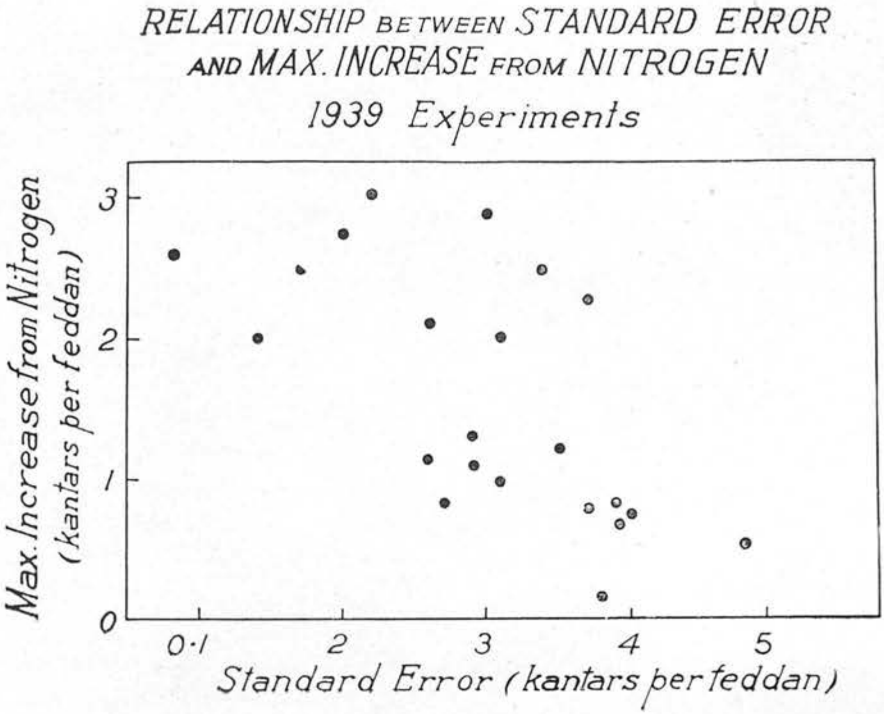
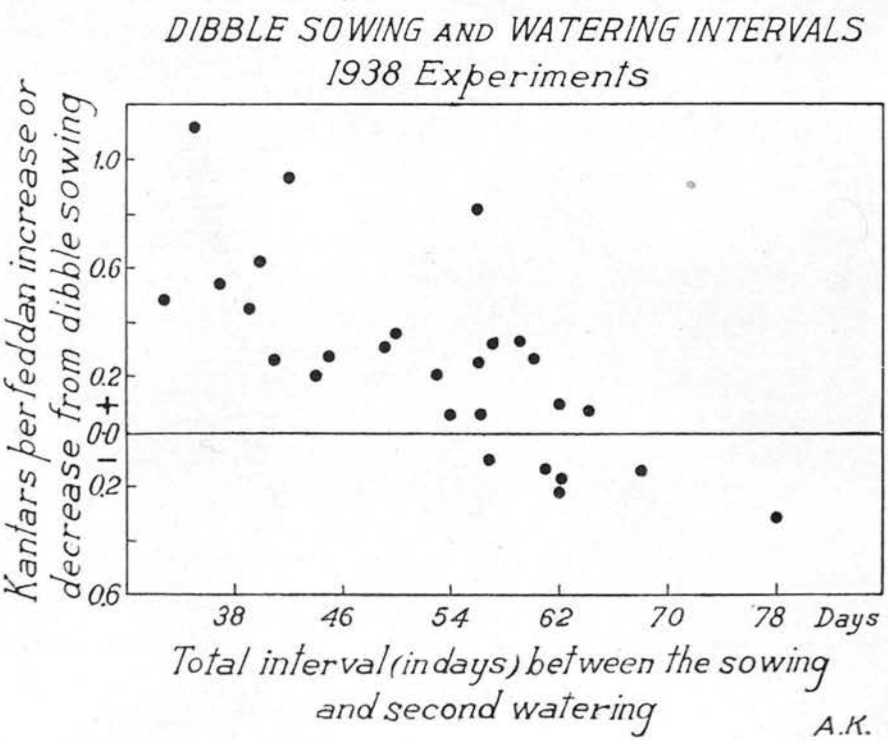

RELATIONSHIP BETWEEN STANDARD ERROR AND MAX. INCREASE FROM NITROGEN
1939 Experiments
Max. Increase from Nitrogen (kantars per feddan)
3
2
1
0
0·1
2
3
4
5
Standard Error (kantars per feddan)

Fig. 4


DIBBLE SOWING AND WATERING INTERVALS
1938 Experiments
Kantars per feddan increase or decrease from dibble sowing
1.0
0.6
0.2
+
0.0
−
0.2
0.6
38
46
54
62
70
78
Days
Total interval (in days) between the sowing and second watering
A.K.

and yield of cotton on the soils of Egypt is, therefore, determined in the first place by the amount of available water (in conjunction, of course, with the nature of the season) Optimum conditions are provided in well-drained soils where the mechanical constitution is such as to allow of the establishment of a satisfactory root system, and at the same time, ensure that the irrigation water supplied will be efficiently utilised.

The following are average figures for the surface (0-25 cm.) layers of normal (fertile) perennially irrigated (alluvial) land in Egypt :—

	Per cent of the air dry soil	In milligram equivalents per cent
Calcium Carbonate	3·00	—
Exchangeable Calcium (CaO)	0·79	28·2
„ Magnesium (MgO)	0·34	16·8
„ Potassium (K_2O)	0·08	1·7
„ Sodium (Na_2O)... ...	traces	—
Total Phosphoric Acid	0·200	—
Available Phosphoric Acid	0·058	—
Total Nitrogen	0·08	—

The calcium carbonate, total and available (exchangeable) potassium, total and available phosphoric acid and total nitrogen all diminish with depth. The exchangeable calcium also decreases with depth but, as the exchangeable magnesium increases, the total of the two remains the same. The saturation capacity for these surface layers averages about 45·0 milligram equivalents per cent and the clay content (particles with diameter less than 0.002 mm.) 47·0 per cent, both features being approximately constant with depth. The pH values average about 8·4 (soil : water ratio 1 : 2·5) and do not vary significantly with depth.

Where a soil is or has been suffering from impeded drainage exchangeable sodium may be present or soluble salts have accumulated (the two do not necessarily go together) so that the physical properties will be adversely affected. In cases of progressive deterioration, the surface layers are generally the last to become involved and root penetration will tend to be increasingly confined to these layers. The natural reaction in such conditions is to give more frequent and/or heavier waterings (salt accumulations). These will be of immediate benefit but, in the absence of remedial measures, must inevitably in due course make matters worse.(1)

(1) *"The Nature of Soil Deterioration in Egypt"* by D.S. GRACIE, M. RIZK, A. MOUKHTAR and A. H. I. MOUSTAFA, Ministry of Agriculture, Egypt, Technical and Scientific Service, Bulletin No. 148 (1934).

Spacing

The proper adjustment of spacing as with irrigation practice, under the conditions created by the pink bollworm, is determined by the necessity for an early crop. The average spacing in general use during the first three years of the experiments (1931-33) was estimated to be 65 cm. between the ridges (eleven ridges per two quassabas) and 25-30 cm. between the holes with two plants per hole, corresponding to about 23-25,000 holes per feddan. The spacing now practised is closer; counts made in seventy-three experiments, which in this merely reflect ordinary cultivation, in the years 1937, 1939 and 1940 gave an average of 28,000 holes per feddan while in seven experiments only was the number less than 24,000. The seventy-three experiments have been split up into three groups according to latitude and the figures for each group separately averaged :—

	Number of experiments	Average number of holes per feddan
North of latitude 31° 00′	10	30,900
Between latitude 31° 00′ and Cairo ...	39	23,000
Upper Egypt	24	27,200
	73	28,000

The averages bring out the well known fact that spacing tends to be widest in the warmer growing conditions of Upper Egypt and becomes closer as one proceeds north, the natural tendency being to compensate for the slower growth of the individual plants by having more of them.

Forty-three actual experiments on spacing were carried out in the three years 1937, 1938 and 1939, twenty-nine of them being in the Delta and fourteen in Upper Egypt (*i.e.* Egypt south of Cairo). The spacings employed were ten, eleven, twelve thirteen and fourteen ridges per two qassabas, equivalent to distances between the ridges varying from 71 to 40 cm., in combination with distances between holes of 35, 25 and 15 cm., giving in all fifteen treatments. The layout was in randomised blocks with four replications. Each experiment was uniformly treated as regards nitrogenous manuring but at varying rates, the amounts given averaging 200 kg. of fertiliser per feddan in Upper Egypt and 130 kg. in the Delta. The results of the experiments are summarised in the Table below where Upper and Lower Egypt are separately treated; the straightforward overall averages, with equal weight to each experiment, are given first and then the averages by seasons.

RESULTS OF THE 1937–1939 SPACING EXPERIMENTS

(Kantars per feddan)

Distance between holes (cm).	Number of ridges per two qassabas *				
	10	11	12	13	14
Average of Twenty-nine Experiments in Delta					
35	6·45	6·73	6·93	7·04	7·06
25	6·80	6·98	7·04	7·28	7·38
15	7·13	7·22	7·36	7·51	7·53
Average of Fourteen Experiments in Upper Egypt					
35	7·68	7·83	7·96	8·09	8·16
25	8·27	8·31	8·18	8·34	8·39
15	8·52	8·58	8·67	8·74	8·73
Average of Fourteen Experiments in Delta in 1937					
35	6·92	7·16	7·37	7·41	7·66
25	7·28	7·47	7·47	7·67	7·87
15	7·64	7·60	7·80	7·91	7·94
Average of Six Experiments in Delta in 1938					
35	5·36	5·58	5·86	5·81	5·85
25	5·73	6·02	6·05	6·22	6·28
15	6·25	6·34	6·37	6·68	6·37
Average of Nine Experiments in Delta in 1939					
35	6·46	6·82	6·95	6·84	6·94
25	6·78	6·88	7·03	7·38	7·37
15	6·94	7·22	7·34	7·43	7·66

* 1 qassaba = 3·55 metres.

Results of the 1937-1939 Spacing Experiments *(contd.)*

(Kantars per Feddan)

Distance between holes (cm.)	Number of ridges per two qassabas * : 10	11	12	13	14
Average of Two Experiments in Upper Egypt in 1937					
35	11·57	11·46	11·71	12·20	11·95
25	12·39	12·38	11·25	12·41	12·73
15	12·47	12·82	12·38	12·71	12·87
Average of Five Experiments in Upper Egypt in 1938					
35	8·06	8·25	8·39	8·15	8·19
25	8·22	8·29	8·35	8·38	8·53
15	8·59	8·62	8·81	9·23	8·90
Average of Seven Experiments in Upper Egypt in 1939					
35	6·29	6·48	6·58	6·86	7·05
25	7·13	7·16	7·18	7·14	7·04
15	6·34	7·34	7·52	7·25	7·43

The overall average figures for both regions show that the closest spacing employed tends to give the highest yield, although with fifteen centimetres between the holes there is very little advantage in having a greater number of ridges than thirteen per two qassabas (a distance apart of 55 cm.)

The most favourable season of the three was 1937 and the poorest 1938, when the month of March was very cold (*see* Tables 10*a* and 10*b*), while the year 1939 can be regarded as having been intermediate between the other two. The necessity for close spacing is easily strongest in the cold spring of 1938, the optimum being abruptly attained in both Lower and Upper Egypt at 15 cm. between the holes and thirteen ridges per two qassabas (51,000 holes per feddan). In the warmer springs of 1937 and 1939 in Upper Egypt, with 15 cm. between the holes, there is little advantage in having more than eleven ridges per

* 1 Qassaba = 3.55 metres.

two qassabas (43,000 holes per feddan) while in the Delta in these years the improvement in yield is continued up to the very closest spacing (55,000 holes per feddan). It is notable that in the Delta in 1937 and to a lesser extent in 1939 a much larger proportion of the total benefit can be secured by narrowing the ridges at the wider distances between the holes, *i.e.* by making the arrangement more symmetrical than is possible in the cold spring of 1938; the emphasis in 1938 is more on closing up along the ridges. Crowther, Tomforde and Ahmed Mahmoud(¹) also found that the closest spacing they employed (15 cm. between the holes with twelve ridges per two qassabas, giving 46 000 holes per feddan) was best in 1935, but that in the more favourable spring of 1936 there was no advantage in spacing closer than 25 cm. between the holes (giving 28,000 holes per feddan), although there was no reduction in yield by doing so. The average of 28,000 holes per feddan obtained from the counts made in the seventy-three experiments would correspond to eleven or twelve ridges per two qassabas with roughly 20 and 25 cm. respectively between the holes.

Since spacing is an important factor in determining the yield level, the nearer it is to the optimum the more efficient will be the utilisation of any nitrogen supplied. The closer spacing necessary in the shorter growing period of today as compared with thirty-five years ago may have created a greater need for nitrogen in any season. Part of this may have arisen in the course of the experiments with the gradual move towards closer spacing (and higher yields), but of this there is no measure.

Average Effects from Nitrogen

The average control plot yields and the average total increases over these control plot yields at each level of nitrogen in each of the sixteen years from 1931 to 1946 are given for all experiments in Table 1 and the corresponding averages for the experiments in the Delta and Upper Egypt (*i.e.* Egypt south of Cairo) separately in Tables 2 and 3. These control plot yields and increases from nitrogen are based on the averages of twelve plots, *i.e.* they include half of any effect from superphosphate; compared with nitrogen average yield effects from superphosphate are, of course, very small.

(¹) Frank Crowther, Adolf Tomforde and Ahmed Mahmoud, "*Further Experiments on the Nitrogenous and Phosphatic Manuring of Cotton*". Bull. No. 30, Royal Agricultural Society, Egypt, 1937.

TABLE 1.—AVERAGE YIELD EFFECTS FROM NITROGEN. ALL EXPERIMENTS
(Kantars per Feddan)

Year	Number of experiments	Average control plot yields	Average total increases			
			O–1N	O–2N	O–3N	O–4N
1931	23	4·60	0·54	0·76	0·84	—
1932	42	4·77	0·68	1·05	1·34	—
1933	29	5·23	0·74	1·22	1·58	—
1934	25	5·12	0·66	1·08	1·36	1·58
1935	25	6·02	0·80	1·30	1·55	1·67
1936	35	5·74	0·71	1·33	1·69	1·93
1937	29	6·98	1·07	1·92	2·34	2·02
1938	31	5·49	0·65	1·04	1·14	1·13
1939	22	5·69	0·74	1·23	1·39	1·47
1940	36	5·67	0·94	1·47	1·85	1·96
1941	35	5·85	0·94	1·35	1·80	1·89
1942	23	5·99	1·18	1·82	2·24	2·28
1943	33	5·43	1·03	1·58	1·85	2·10
1944	30	6·35	0·99	1·42	1·68	1·70
1945	34	5·86	0·93	1·45	1·85	1·92
1946	34	5·95	0·93	1·56	1·79	1·94
Averages	491/16	5·67	0·85	1·35	1·64	(1·86)

TABLE 2.—AVERAGE YIELD EFFECTS FROM NITROGEN IN UPPER EGYPT
(Kantars per Feddan)

Year	Number of experiments	Average control plot yields	Average total increases			
			O–1N	O–2N	O–3N	O–4N
1931	8	5·05	0·64	0·88	0·92	—
1932	16	4·90	0·90	1·29	1·73	—
1933	10	5·94	0·95	1·48	1·88	2·05
1934	7	5·81	0·83	1·27	1·57	1·84
1935	4	7·25	1·08	1·89	2·30	2·40
1936	8	6·86	0·68	1·25	1·61	1·88
1937	9	7·91	1·17	2·02	2·34	2·63
1938	10	6·43	0·77	1·23	1·22	1·12
1939	6	5·23	0·75	1·25	1·48	1·59
1940	14	5·36	1·18	1·95	2·38	2·41
1941	14	5·40	0·97	1·48	1·98	2·04
1942	13	5·92	1·50	2·18	2·45	2·44
1943	13	6·04	1·51	2·19	2·76	3·05
1944	14	6·10	1·07	1·74	2·21	2·15
1945	14	5·60	1·19	1·8[illegible]	2·40	2·68
1946	13	6·95	0·87	1·73	2·06	2·35
Averages	173/16	6·05	1·00	1·60	1·96	(2·19)

Fig. 5

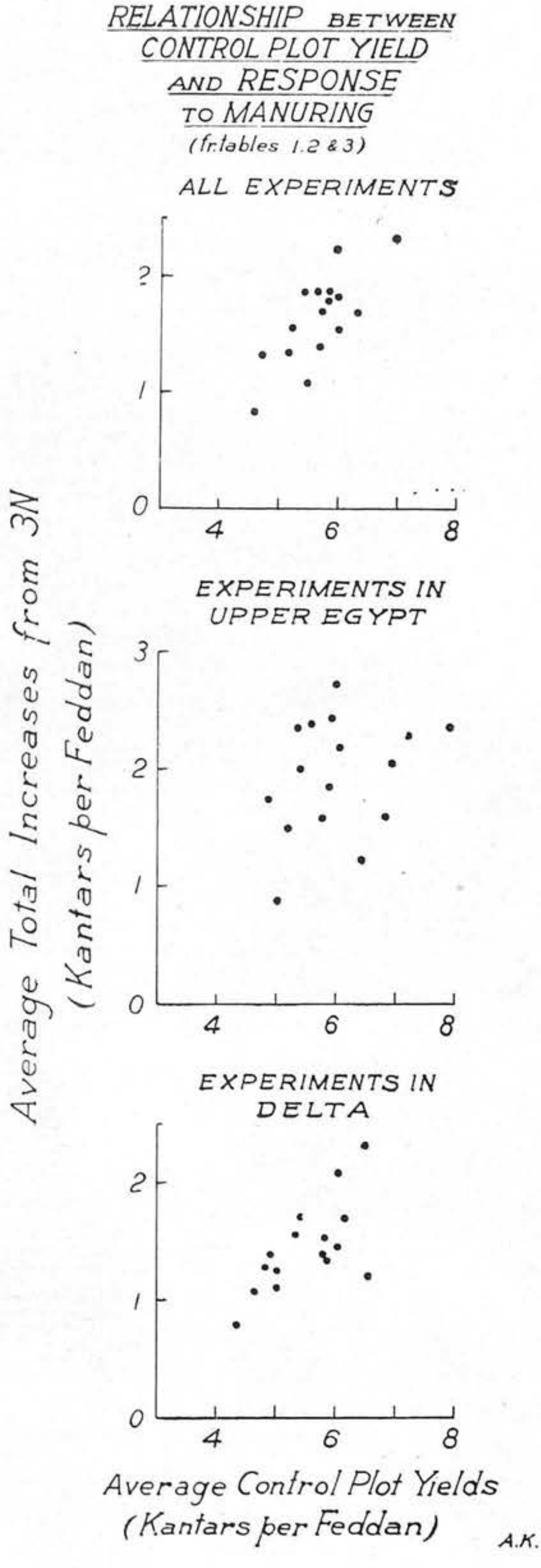

RELATIONSHIP BETWEEN
CONTROL PLOT YIELD
AND RESPONSE
TO MANURING
(fr. tables 1.2 & 3)
ALL EXPERIMENTS
EXPERIMENTS IN
UPPER EGYPT
EXPERIMENTS IN
DELTA
Average Total Increases from 3N
(Kantars per Feddan)
Average Control Plot Yields
(Kantars per Feddan)
0
1
2
3
4
6
8
A.K.

TABLE 3.—AVERAGE YIELD EFFECTS FROM NITROGEN IN THE DELTA

(Kantars per Feddan)

Year	Number of experiments	Average control plot yields	Average total increases			
			0–1N	0–2N	0–3N	0–4N
1931	15	4·36	0·49	0·70	0·81	—
1932	26	4·68	0·55	0·92	1·11	—
1933	19	4·93	0·63	1·09	1·42	—
1934	18	4·86	0·59	1·00	1·28	1·48
1935	21	5·79	0·75	1·19	1·41	1·53
1936	27	5·41	0·72	1·35	1·71	1·95
1937	20	6·56	1·02	1·87	2·33	2·61
1938	21	5·04	0·59	0·95	1·10	1·14
1939	16	5·87	0·74	1·27	1·35	1·43
1940	22	5·86	0·78	1·17	1·51	1·68
1941	21	6·15	0·92	1·27	1·68	1·80
1942	15	6·06	0·90	1·52	2·05	2·13
1943	20	5·03	0·72	1·18	1·26	1·47
1944	16	6·57	0·92	1·14	1·22	1·30
1945	20	6·05	0·80	1·18	1·46	1·39
1946	21	5·34	0·96	1·46	1·61	1·68
Averages ...	318/16	5·54	0·77	1·20	1·46	(1·66)

The average increases in the proportion of the crop obtained at the second picking and respectively corresponding to the average yield figures of Tables 1, 2 and 3 are given in Tables 4, 5 and 6. Yield effects from nitrogen in Upper Egypt (Tables 5 and 6) are much less dependent on picking the late bolls than in the Delta and the proportion of experiments without a second picking higher. Similarly the Delta experiments could be split up to show that those with one picking occur in the south and that two pickings are almost the invariable rule in the north.

TABLE 4.—AVERAGE INCREASES IN THE PROPORTION OF THE CROP AT THE SECOND PICKING (All Experiments).

Year	Number of experiments	Number of experiments having a second picking	Percentage increases in moving from:			
			0–1N	0–2N	0–3N	0–4N
1931	23	22	0·4	1·6	3·0	—
1932	42	40	1·7	4·1	6·0	—
1933	29	28	2·3	4·8	7.0	—
1934	25	24	1·3	3·5	4.6	7·2
1935	25	24	1·5	5·0	6·2	8·6
1936	35	34	1·1	3·0	4·4	6·0
1937	29	28	2·4	5·2	7·8	9·6
1938	31	25	2·6	5·3	7·5	8·7
1939	22	19	1·5	4·2	6·7	9·4
1940	36	27	2·6	4·7	6·8	8·7
1941	35	24	1·2	1·9	3·8	6·0
1942	23	22	0·7	3·3	4·4	6·5
1943	33	27	2·1	2·5	4·3	5·4
1944	30	18	2·7	3·4	4·9	6·6
1945	34	20	2·4	4·0	6·2	6·8
1946	34	22	2·2	2·9	4·7	6·0
Total and Averages ..	491	404	—	—	—	—

TABLE 5.—AVERAGE ALTERATIONS IN PROPORTION OF THE CROP AT THE SECOND PICKING (Upper Egypt).

Year	Number of experiments	Number of experiments with a second picking	Percentage alterations in moving from:			
			0–1N	0–2N	0–3N	0–4N
1931	8	7	0·4	2·4	2·6	—
1932	16	14	1·5	3·2	4·9	—
1933	10	8	2·5	5·5	7·3	9·8
1934	7	7	0·4	1·3	1·3	3·2
1935	4	3	1·5	3·7	6·2	5·4
1936	8	7	3·2	5·5	7·6	8·3
1937	9	9	2·0	2·9	4·2	5·3
1938	10	6	2·9	5·2	7·7	8·1
1939	6	5	0·0	4·0	5·8	7·8
1940	14	11	0·7	2·1	3·9	4·7
1941	14	11	0·4	1·4	2·3	3·9
1942	13	10	−0·7	0·6	1·1	2·0
1943	13	8	−0·6	0·1	1·0	1·3
1944	14	6	−0·6	−0·4	1·1	3·0
1945	14	7	3·2	4·7	8·0	9·3
1946	13	7	2·9	4·4	9·1	9·1
Total and Averages ..	173	126 or 72·8%	1·2	2·9	4·6	—

Fig. 6

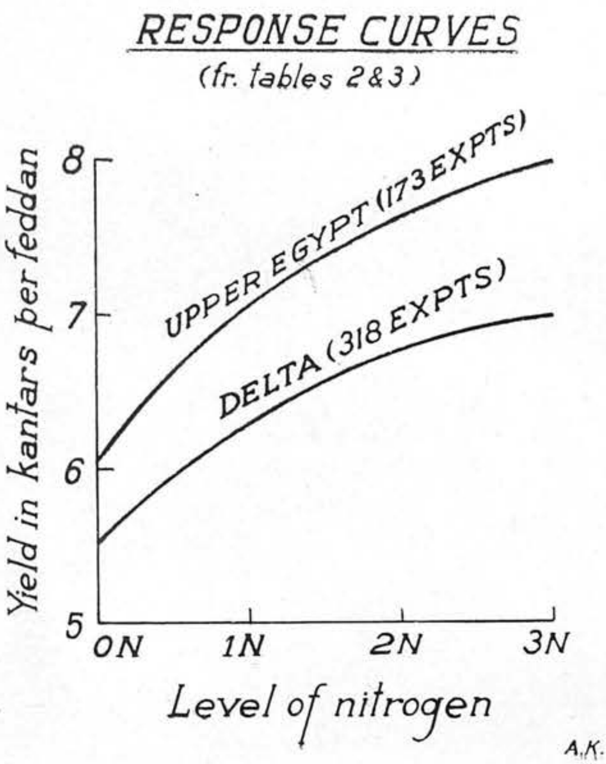

RESPONSE CURVES
(fr. tables 2&3)
UPPER EGYPT (173 EXPTS)
DELTA (318 EXPTS)
Yield in Kantars per feddan
8
7
6
5
0N
1N
2N
3N
Level of nitrogen
A.K.

TABLE 6.— AVERAGE INCREASES IN PROPORTION OF THE CROP AT THE SECOND PICKING (D..LTA)

Year	Number of experiments	Number of experiments having a second picking	Percentage increases in moving from :			
			0–1N	0–2N	0–3N	0–4N
1931	15	13	0·3	1·1	2·6	—
1932	26	26	2·0	4·8	6·2	—
1933	19	19	2 2	4·5	6·8	—
1934	18	18	1·6	4·3	5·9	8·7
1935	21	21	1·6	5·2	6 1	8·6
1936	27	27	0·6	2·4	3·6	5·4
1937	20	19	2·6	6·2	9·3	11·6
1938	21	19	2·4	5·4	7·4	8·8
1939	16	14	2·0	4·3	7·0	10·0
1940	22	16	3·9	6·4	8·9	11·7
1941	21	13	2·0	2·8	5·1	7·7
1942	15	13	1·6	5·4	7·3	9·9
1943	20	9	3·2	3·6	5·7	7·1
1444	16	12	4·3	5·3	6·8	8·4
1945	20	13	2 0	3·0	5·2	6 2
1946	21	16	1·9	2·2	4·3	5·9
Totals and Averages ..	318	278 or 87·4%	2·1	4·2	6·1	—

If, as in Fig. 5, the average increases at 3N of Tables 1, 2 and 3 are plotted against the average control plot yields over which they were obtained the central feature of the results is brought out, namely, that large returns from fertiliser nitrogen are possible only where the level of yield (as represented by the control plot yield) is already high. The relationship is much closer in the Delta than in Upper Egypt and the average return from nitrogen less. This is because, although the response in both regions is subject to large seasonal variations (which also affect the control plot yields), yet the generally higher temperatures of the growing season in Upper Egypt will be shown to permit of a larger return from nitrogen there in any season. Even where the average control plot yields in Upper Egypt have been lower than in the Delta, as in 1939, 1940, 1944 and 1945, the increases recorded over them are consistently higher. Moreover 1943, the best year for fertiliser (but not for highest production) in Upper Egypt, was a poor one in the Delta.

The response curves for the two regions, drawn from the averages at the bottom of Tables 2 and 3, are given in Fig. 6 ; the difference in favour of Upper Egypt is a quarter of a kantar at IN increasing to half a kantar at 3N.

In Figs. 7*a* and 7*b* the average increases in yield from nitrogen of Table 1 have been set against the average increases in the proportion of the crop at the second picking of Table 4 with which they are associated. The points for the six years 1931–1935 and 1939 are shown separately in Fig 7*a*. As they fall approximately in the same straight line the results for these six years have been averaged and are shown as the central line in figure 7*b*, with the points for 1936, 1937 and 1940 lying above it and those for 1938 below it. Two effects are apparent in the diagrams; the length to which a line of points is prolonged represents the extent to which yield effects from nitrogen depended on picking the late-formed bolls while the direction which it takes is a reflection of the extent to which fertiliser nitrogen was able to influence the production of early bolls. Thus the effect on early bolls was at a minimum in the cold spring of 1938 and at a maximum in the warm ones of 1936 and 1937 and the notable difference in yield effects between the last two years is mainly due to the fact that fewer late bolls were picked in 1936 than in 1937. The points for the years 1941–1946 are not included in the diagrams but they would all lie above the central line of Fig. 7*b*; the average increase in the proportion of the crop at the second picking in these years was small so that return from nitrogen depended mainly on the stimulation of the early bolls. [The late bolls of Upper and Lower Egypt have been dealt with together here for the sake of convenience in illustration but when the conditions controlling their production and survival come to be considered the two regions must be treated independently; a year in which late bolls can be picked in Upper Egypt may be a poor one for them in the Delta, and vice versa.]

Influence of Sowing Date

The nature of the seasonal variation as regards the early bolls is best appreciated by a consideration of the variation in the relationships between sowing date, control plot yield and maximum increase from nitrogen in the individual experiments for each year. (The maximum increases over the control plot yields have been taken out irrespective of the nitrogen level at which they occur.) Tables 7, 8 and 9 give the average values for these factors and the total correlation coefficients which have been calculated between them respectively for the experiments in Upper Egypt, for the Delta as a whole, and for that part of the Delta lying north of latitude 30° 45′, *i.e.* north of a line passing through Tanta and Zagazig. The mean maximum and minimum temperatures for the months of February to August inclusive are given in Tables 10*a* and 10*b*; they are the averages for the two stations of Minia and Assiut in Upper Egypt (Table 10*a*) and for the three stations of Tanta, Zagazig and Giza in the Delta (Table 10*b*).

Fig. 7

RELATIONSHIP BETWEEN YIELD EFFECTS FROM NITROGEN AND THE INCREASE IN THE PROPORTION OF THE CROP AT THE SECOND PICKING

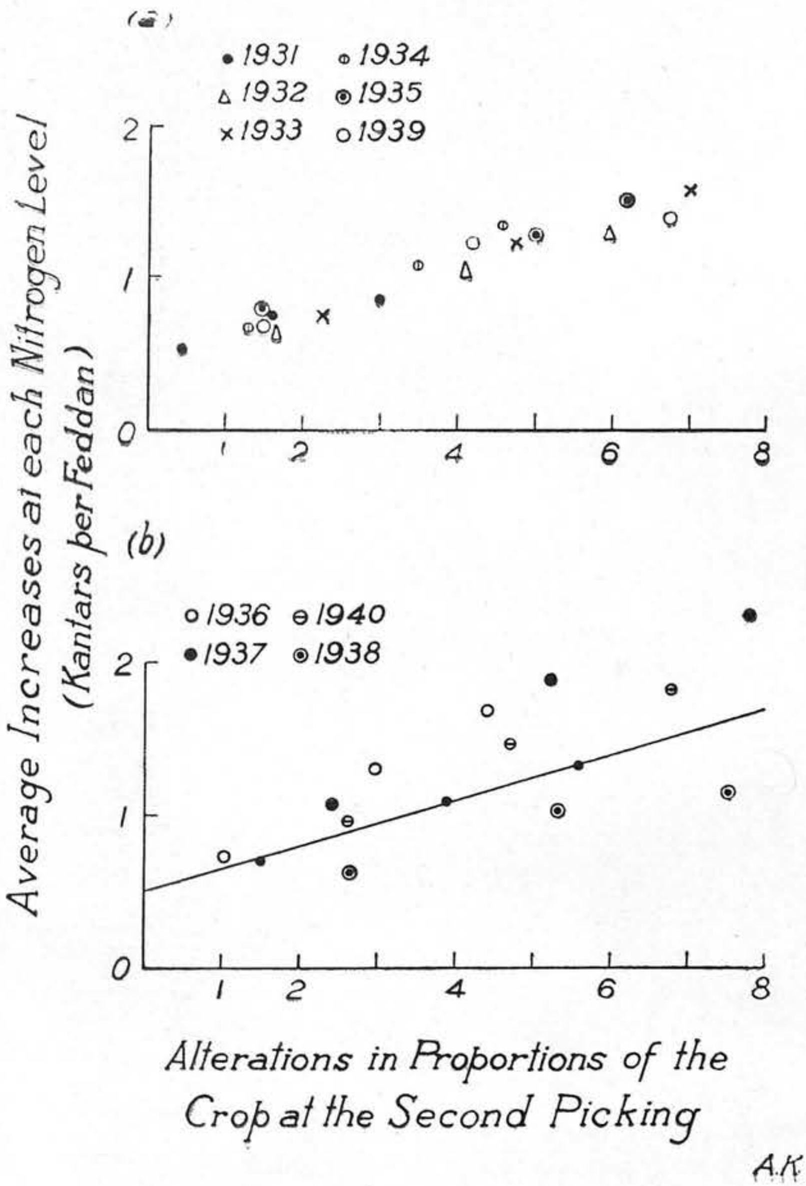


TABLE 7.—RELATIONSHIP BETWEEN SOWING DATE, CONTROL PLOT YIELD AND MAXIMUM INCREASE FROM NITROGEN (Upper Egypt).

Year	Number of experiments	Number after berseem catch crop	I Average sowing date	II Average control plot yield (kantars per feddan)	III Average maximum increases from nitrogen (kantars per feddan)	Total correlations between: I and II	I and III	II and III
1931	8	—	8/3	5·05	1·10	—	—	—
1932	16	2	7/3	4·90	1·99	±·00	—·07	—·16
1933	10	2	23/2	5·94	2·15	+·14	+·20	+·65*
1934	7	1	3/3	5·81	2·21	—	—	—
1935	4	1	22/2	7·25	2·48	—	—	—
1936	8	1	21/2	6·86	1·99	—	—	—
1937	9	1	27/2	7·91	2·92	—·20	—·15	—·38
1938	10	1	27/2	6·43	1·52	+·21	—·22	—·41
1939	6	—	1/3	5·56	1·67	—	—	—
1940	14	1	3/3	5·36	2·67	±·00	—·54*	—·45
1941	14	1	21/2	5·40	2·30	+·02	—·40	—·23
1942	13	2	3/3	5·92	2·66	+·23	—·50	—·33
1943	13	4	5/3	6·04	3·15	—·16	—·55*	—·49
1944	14	6	10/3	6·10	2·31	+·02	—·20	—·64*
1945	14	4	12/3	5·60	2·75	—·42	—·25	—·29
1946	13	3	6/3	6·95	2·50	+·23	—·18	—·32

* Correlation significant at 20 : 1.

TABLE 8.—RELATIONSHIP BETWEEN SOWING DATE, CONTROL PLOT YIELD AND MAXIMUM INCREASE FROM NITROGEN

Year	Number of experiments	I Average sowing date	II Average control plot yield (kantars per feddan)	III Average maximum increase from nitrogen (kantars per feddan)	Total correlations between: I and II	I and III	II and III
				Delta			
1931	15	11/3	4·36	0·88	—·52*	—·26	—·25
1932	26	15/3	4·68	1·17	—·38*	—·04	+·31
1933	19	12/3	4·93	1·45	—·64*	—·40	+·41
1934	18	10/3	4·86	1·66	—·25	—·25	+·14
1935	21	3/3	5·79	1·61	—·01	+·04	+·08
1936	27	10/3	5·41	2·00	—·11	—·62*	—·06
1937	20	7/3	6·56	2·66	—·16	—·57*	—·26
1938	21	9/3	5·04	1·22	—·57*	—·25	+·15
1939	16	14/3	5·87	1·58	—·60*	+·22	—·49*
1940	22	13/3	5·86	1·76	—·30	—·01	+·20
1941	21	8/3	6·15	1·94	—·51*	+·21	—·53*
1942	15	11/3	6·06	2·25	—·20	+·15	+·21
1943	20	14/3	5·03	1·52	—·30	—·47*	+·74*
1944	16	15/3	6·57	1·57	—·70*	—·16	+·16
1945	20	12/3	6·05	1·63	—·05	+·59*	+·02
1946	21	11/3	5·34	1·97	—·55*	+·40	—·19

TABLE 9.—RELATIONSHIP BETWEEN SOWING DATE, CONTROL PLOT YIELD AND MAXIMUM INCREASE FROM NITROGEN.

Year	Number of experiments	I	II	III	I and II	I and III	II and III
				Experiments North of Latitude 30° 45'			
1932	16	17/3	4·17	0·89	+·16	+·11	+·25
1933	12	16/3	4·48	1·41	—·37	—·26	+·27
1934	12	12/3	4·12	1·34	+·50	—·19	—·13
1935	14	5/3	5·66	1·45	—·05	+·20	+·10
1936	19	12/3	5·36	2·01	—·31	—·68*	±·00
1937	11	10/3	5·97	2·70	—·31	—·56	+·14
1938	13	12/3	4·51	1·26	—·69*	—·32	+·47
1939	12	17/3	5·39	1·56	—·54	+·31	—·64*
1940	15	16/3	6·02	1·95	—·40	—·15	+·08
1941	15	9/3	6·03	2·10	—·59*	+·01	—·44
1942	9	13/3	5·85	2·43	±·00	—·05	+·49
1943	12	16/3	4·55	1·38	—·23	—·44	+·69*
1944	10	18/3	5·93	1·37	—·77*	+·09	+·21
1945	13	14/3	6·37	1·60	—·35	+·64*	—·67*
1946	14	12/3	5·34	1·79	—·52*	+·68*	—·37

* Correlation significant at 20 : 1.

TABLE 10*a*.—MEAN MAXIMUM AND MINIMUM TEMPERATURES (°C.) AT MINIA AND ASSIUT (Upper Egypt)*

Year	February		March		April		May		June		July		August	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1931	21·4	6·5	27·8	9·9	30·9	14·1	34·0	17·9	35·9	20·9	37·2	22·6	37·4	22·8
1932	2[illegible]·7	6·1	26·2	9·8	30·7	13·0	33·2	16·4	36·9	20·8	38·2	22·5	—	22·2
1933	24·4	7·8	26·1	9·8	28·1	11·6	34·7	—	39·6	21·1	35·9	20·7	35·5	20·7
1934	19·8	5·0	27·7	10·4	32·1	13·9	35·7	19·2	37·1	20·5	36·7	21·2	36·7	21·1
1935	22·6	8·4	27·4	10·6	31·4	13·3	37·0	19·5	37·6	21·7	35·7	20·8	36·0	21·9
1936	24·7	9·2	28·[illegible]	11·[illegible]	33·0	15·3	35·4	19·0	37·1	20·0	37·6	22·5	36·5	22·8
1937	23·7	7·7	27·6	10·4	32·2	14·5	35·1	18·4	35·2	19·8	36·9	22·0	36·5	22·1
1938	20·7	7·2	23·2	8·3	30·7	13·9	34·5	17·5	34·8	19·2	37·3	22·2	36·8	22·8
1939	21·8	7·5	25·[illegible]	10·4	30·8	13·6	38·2	19·7	36·5	20·2	36·4	21·4	35·9	21·8
1940	23·2	8·2	25·8	9·9	31·1	15·1	36·0	18·7	38·4	21·2	36·6	21·6	36·6	21·4
1941	25·7	9·7	26·5	10·8	31·7	14·8	39·9	20·3	36·6	20·1	37·8	22·0	37·3	22·4
1942	23·2	7·8	26·6	11·4	33·3	14·7	36·3	18·6	37·6	[illegible]1·3	36·7	21·6	35·6	21·7
1943	20·8	(6·1)	23·9	8·6	27·2	11·5	33·8	18·0	35·1	19·3	37·5	21·9	36·9	22·1
1944	22·9	6·7	26·3	10·3	32·1	14·3	33·3	17·3	38·5	21·4	36·7	21·6	36·9	21·7
1945	20·1	6·2	22·6	7·3	29·5	12·3	36·5	19·7	35·1	19·9	37·6	22·0	38·6	22·6
1946	21·5	6·7	25·2	9·7	31·0	13·7	35·5	18·6	36·9	21·5	37·6	22·0	37·8	22·3

(*) Figures are taken from the "*Meteorological Reports*" of the Physical Department, Ministry of Public Works, from 1931–1939 and thereafter, from the Physical Department and from the Meteorological Department of the Ministry of War and Marine.

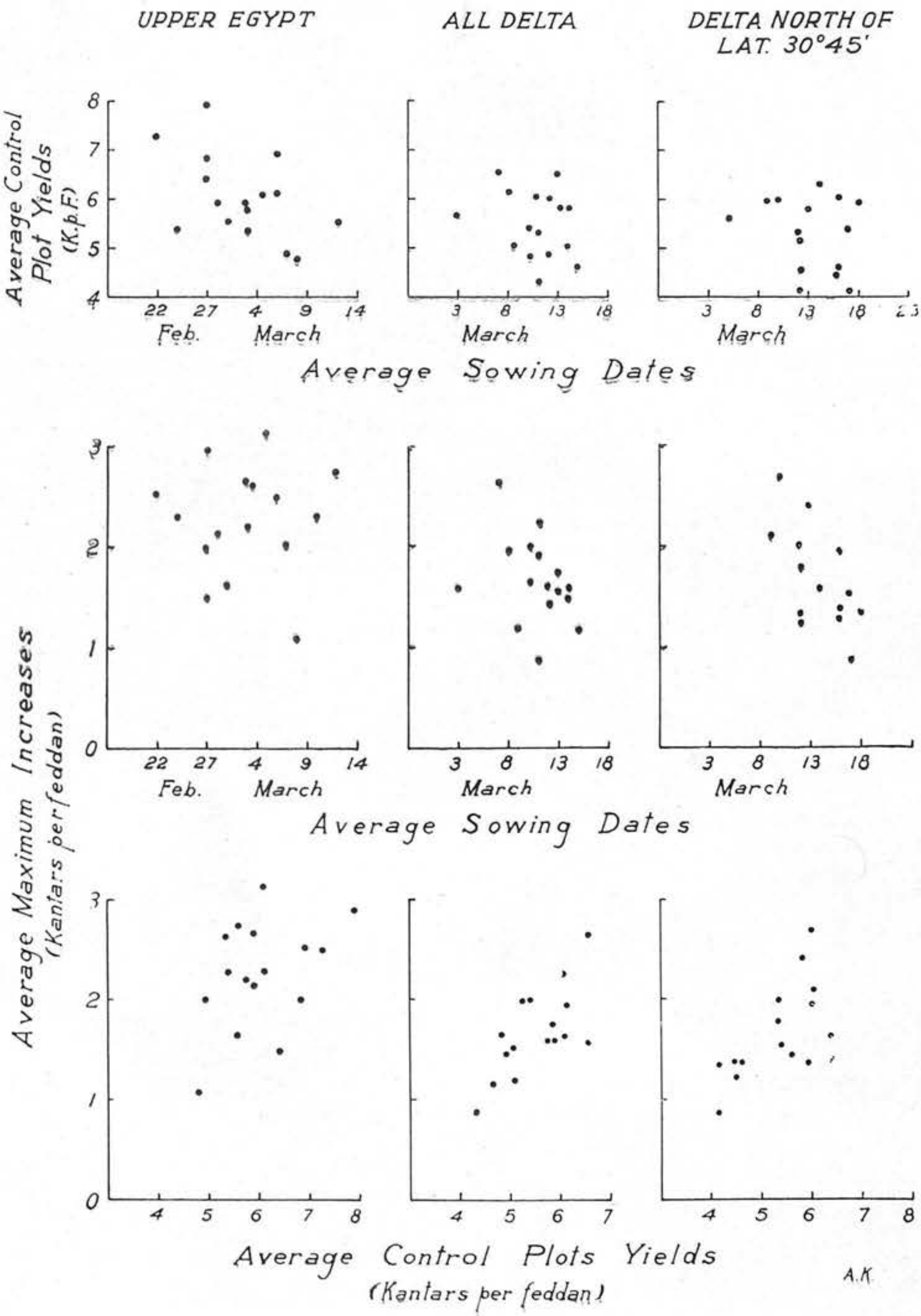
TABLE 10.*b*—MEAN MAXIMUM AND MINIMUM TEMPERATURES (°C.) AT TANTA, ZAGAZIG AND GIZA (DELTA.)

Year	February		March		April		May		June		July		August	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1931	21·7	6·1	26·3	9·0	28·6	12·0	31·6	15·0	34·1	18·5	36·2	20·5	36·4	20·8
1932	21·3	6·3	24·8	8·6	27·9	10·2	31·0	13·4	34·9	17·5	36·6	19·6	34·7	20·2
1933	22·2	7·1	23·5	8·3	25·7	8·3	31·6	14·0	35·5	18·1	33·6	18·6	33·6	18·4
1934	18·1	4·5	25·1	8·3	28·9	11·1	31·5	15·9	35·1	18·1	34·8	19·3	34·8	19·7
1935	21·9	7·2	24·5	8·8	29·1	10·8	33·8	15·6	35·0	18·7	34·3	18·6	34·1	19·2
1936	22·7	7·7	25·1	9·2	29·7	12·3	31·4	15·4	33·9	17·3	35·5	20·5	34·1	20·3
1937	22·8	6·6	25·5	8·7	29·2	12·2	31·3	14·8	33·5	17·6	35·0	19·6	34·4	20·0
1938	19·7	5·8	21·5	7·0	27·8	11·3	31·2	13·7	33·6	17·0	35·6	20·4	34·8	20·5
1939	20·7	6·5	23·9	8·7	28·6	11·4	34·1	16·1	33·6	17·3	34·9	19·7	34·3	19·9
1940	22·2	6·7	24·1	7·7	28·6	12·3	32·0	15·2	35·3	17·7	35·5	19·4	33·4	18·8
1941	24·4	6·9	23·8	8·9	29·1	11·2	35·5	16·1	33·8	16·8	35·3	19·1	35·1	19·5
1942	22·4	6·4	24·1	9·2	29·8	11·2	33·2	14·9	35·8	18·7	35·0	19·9	33·9	18·9
1943	20·4	5·7	21·7	7·2	25·4	8·9	31·0	14·1	32·7	16·3	35·4	18·8	35·2	20·1
1944	22·2	6·7	24·7	8·7	29·4	11·4	30·6	14·4	35·4	18·9	34·9	20·1	34·5	20·0
1945	19·1	6·1	20·8	6·4	26·3	9·9	33·2	16·1	33·5	17·8	35·5	20·4	36·2	20·6
1946	(20·5)*	(6·1)	23·7	8·1	27·8	(11·2)	(32·0)	(15·1)	(34·4)	(18·6)	35·1	(19·9)	35·5	(20·3)

(*) The figures in brackets are the averages for the two stations only of Tanta and Giza.

Fig. 8

RELATIONSHIPS BETWEEN AVERAGE SOWING DATES AVERAGE CONTROL PLOT YIELDS AND AVERAGE MAXIMUM INCREASES FROM NITROGEN



Upper Egypt.—In five of the years in Upper Egypt the number of experiments is too few to permit of the calculation of the correlations. In the eleven for which they exist the yields of the control plots in *individual* experiments have been comparatively indifferent to the dates on which they were sown, the coefficients varying from small negative through zero to small positive values.

It is a very different matter where benefit from nitrogen is concerned; there are consistent negative (the year 1933 excepted) associations between sowing date and maximum increase from nitrogen and between the latter and control plot yield, though they seldom reach actual significance. Benefit from nitrogen tends to be greatest on early sown cotton and where control plot yield is limited because of an inadequate supply of nitrogen in the soil.

The fact that there is little connection between sowing date and control plot yield in individual experiments does not apply to the average values for each year; these show a decided negative relationship (Fig. 8). As against this the negative correlation between sowing date and increase from nitrogen of individual experiments disappears when the average annual figures are considered while the one between control plot yield and maximum increase actually becomes positive (Fig. 8). When the results for Upper Egypt are considered by *seasons*, therefore, the average extent to which it has been possible to sow early becomes important for average control plot yield and increase in the latter means increased return from manure.

The only year in which control plot yield was positively (and significantly) associated with maximum increase from nitrogen in individual experiments was in 1933. This exceptional result is probably connected with the fact that the month of June in that year in Upper Egypt was easily the hottest of the series (*see* Table 10*a*), the effect of which would be all the greater as it followed on reasonably cool weather in April and May. Under such conditions of severe water strain it is reasonable to suppose that cotton on the better soils would show the greatest resistance.

Delta.—The indifference shown in Upper Egypt by the control plot yields of *individual* experiments to the dates on which they were sown does not extend to the Delta. In that region there is a constant emphasis (Table 8) on the need for early sowing to secure high control plot yield, the (negative) association being significant in eight years out of the sixteen, although in some years it has a very low value. It remains almost as consistently negative for the experiments north of latitude 30° 45′ (Table 9), becoming positive only in 1932 and especially in 1934 when the month of February was unusually cold.

In direct contrast also to what was found in Upper Egypt there are no consistent relationships in the individual experiments between sowing date and maximum increase from manuring or between the latter and control plot yield; they may be positive or negative, according to season. Early-sown cotton tended to benefit most from fertiliser nitrogen (negative correlations) in the Delta as a whole in ten out of the sixteen years, the association reaching significance in three (1936, 1937 and 1943); in the six years in which late-sown cotton tended to give the best response (positive correlations) the relationship was significant in two (1945 and 1946). What will be termed the "normal" expectation in the Delta is fulfilled when both yield without manure and increase from its use are sufficiently dependent on early sowing as to render the relationship between the two positive; high response to nitrogen then tends to be a feature of land that is already high yielding although it became a significant one only in 1943. This "normal" expectation was entirely reversed in the Delta as a whole in 1939 and 1941 and in the northern half in 1945 when factors other than early sowing became of greater importance for maximum increase and response was significantly better at the lower yield levels.

A consideration of the average difference *between years* brings out a change over in the emphasis of sowing date as between control plot yield and maximum increase of a nature similar to what has been shown for Upper Egypt but having the opposite meaning; early sowing remains a desirable thing for control plot yield but is of greater importance for increase from nitrogen (Fig. 8). The strongest expression of the seasonal effect is consequently found in the relationship between control plot yield and return from fertiliser; these increase and decrease together, as they do in Upper Egypt, but in a more marked manner, because the possibilities in the Delta are more restricted in any season.

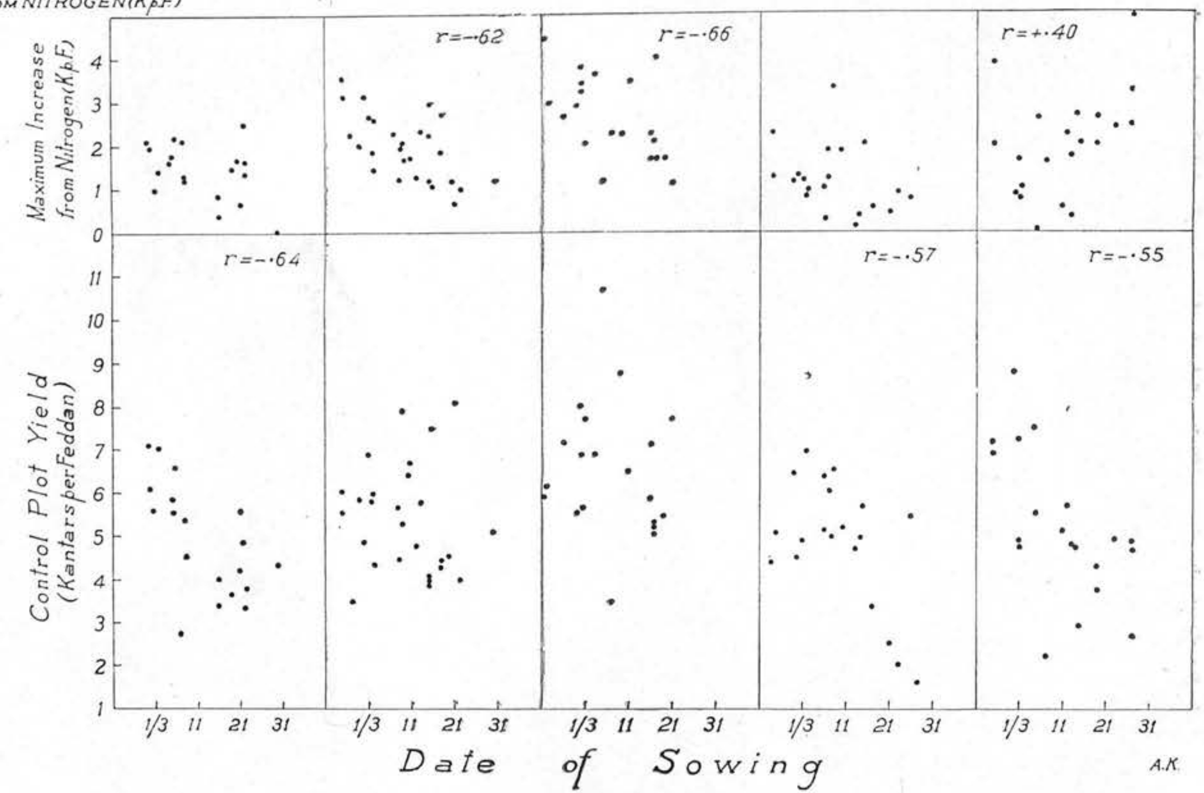
Sowing Date and Spring Temperatures

These variations in the influence of sowing date according to season and locality are in reality a reflection of the temperatures experienced in the early part of the growing season. They are illustrated in Fig 9 where the control plot yields and maximum increases from nitrogen have been plotted against the dates of sowing for individual experiments in the Delta for the years 1933, 1936, 1937, 1938 and 1946. The mean maximum temperatures for the month of March are given at the top of the diagram as well as the average maximum increases from manuring in kantars per feddan. The months of April, May

Fig 9

RELATIONSHIP BETWEEN SOWING DATE CONTROL PLOT YIELDS AND MAXIMUM INCREASES FROM NITROGEN IN DELTA

YEAR	1933	1936	1937	1938	1946
MEAN MAX. TEMP. IN MARCH (°C)	23·5	25·1	25·5	21·5	23·9
AV. MAX. INCREASE FROM NITROGEN (K.p.F.)	1·45	2·00	2·66	1·22	1·97



and June in the first four of these years were reasonably or even very cool with the exception of June in 1933 which was rather warm (*see* Table 10) Marked stimulation of early boll production in the Delta is only possible in years such as 1936 and 1937 in which March temperatures are high and the weather in the following months reasonably satisfactory ; and the extent of stimulation possible (it varies from less than one to over four kantars) is determined by the degree to which advantage has been taken of these higher temperatures, as represented by the sowing date. In these two years the influence of sowing date on control plot yield or of the latter on increase from fertiliser is slight. Where spring temperatures are lower on the other hand, owing to the slower growth rate, the possibility of such stimulation is diminished and date of sowing becomes important mainly for control plot yield.

Similar considerations apply to Upper Egypt. Temperatures being higher, there is on the whole more latitude as regards sowing date in any season and a consequent relative indifference of the control plot yields to the dates on which they are sown in the experiments within any one year. Correspondingly early sowing becomes important for return from nitrogen and the latter has a greater effect on yield in Upper than in Lower Egypt.

There is a well marked optimum sowing date (1) which gets earlier as one moves from north to south but which will, of course, at any one locality vary from year to year according to season. The average sowing dates employed in the sixteen years of the experiments are the 13th of March in the northern half of the Delta, the 10th of March for the Delta as a whole, and the 3rd of March in Upper Egypt. Fig. 18 (2) shows that the limits to earliness in sowing in Upper Egypt are set by the mean minimum temperatures in February. The average sowing dates used in the diagram have been arrived at omitting the experiments after berseem ; cotton grown after berseem will be shown to be later sown than the general run and the number of experiments after the crop in Upper Egypt are very unevenly distributed in time (*see* Table 7). It should also be noted that no special benefit appears to have been derived in the Delta from the very early sowings of 1935 (*see* Fig. 8 and Table 8).

Factors Affecting the Late Bolls

While the extent to which nitrogen can affect early boll production is controlled by the temperatures experienced in the first part of the growing season the possibilities as regards the late bolls are largely decided by the temperatures in late summer.

(1) For results of sowing date experiments *see* :—
" *Dibble-Sowing of Cotton, Method Effect and Profit* ", by W. L. Balls and D. S. Gracie. Tech. Bull. No. 229, Ministry of Agriculture, Egypt (1939).

(2) These average sowing dates are, of course, a sample of those actually employed in ordinary cultivation.

The direct connection in the Delta between the number of late bolls harvested and the mean maximum August temperatures is shown in Fig 10 *a*; excessive heat in that month causes undue shedding. The maximum temperatures in July also have some influence and the point displaced to the left in the diagram, for example, is for 1936 when the second half of the month was very hot (1).

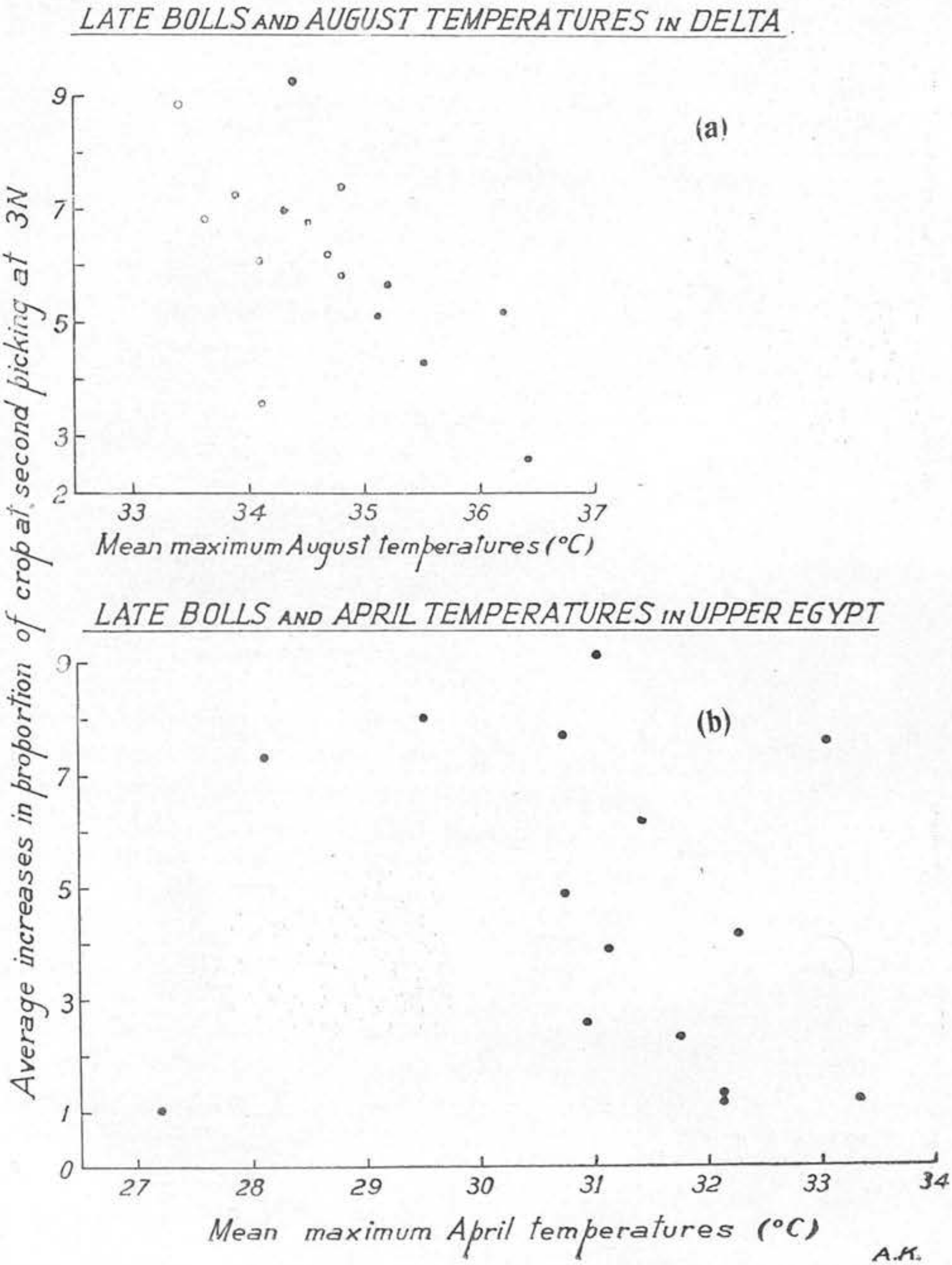
By comparison with the Delta any summer in Upper Egypt is hot and yield effects from nitrogen (Tables 5 and 6) are in consequence less dependent, on the whole, on picking the late bolls. This temperature gradient is the reason why the proportion of experiments in which a second picking was not worth while is highest in Upper Egypt and that in the Delta those with one picking occur in the south while two pickings are almost the invariable rule in the north. The number of late bolls that are picked in Upper Egypt depends in part at least on what conditions were like earlier in the season; Fig 10 *b* shows that where growth has been restricted by low temperatures in April there is a tendency for it to be prolonged. No such connection can be demonstrated between spring temperatures and late bolls in the Delta.

Seasonal Effects in General

Temperatures have been treated arbitrarily as above purely for the sake of convenience in discussion; it is obvious that each season should be treated separately as a whole. The number of late bolls which can be picked in Upper Egypt, for example, has just been shown to depend on the growing weather in April, but no similar relationship has been established between the temperatures in that month and production in Upper Egypt as a whole. In the same way a large return from nitrogen in the Delta can only be obtained if the weather in March is suitable but it does not necessarily follow once that condition is satisfied. The most favourable March temperatures of the series in the Delta occurred in 1931 and were succeeded by very suitable months of April, May and June. The crop in that year with its enlarged vegetative growth then passed into the hottest (combined) months of July and August of the sixteen in a condition in which it was least able to withstand them; the severe water strain and heat injury resulted in such abnormal shedding that both control plot yield and return from manure were the lowest experienced. The appearance of red leaf in cotton towards the end of the season was extremely common in that year, even the remaining bolls, ordinarily green, taking on a bright red colour. There is a suspicion that these adverse conditions may have been aggravated by a shortage of summer water since the area allowed under rice in 1931 was very small

(1) The month of July was hottest in 1932.

Fig. 10


LATE BOLLS AND AUGUST TEMPERATURES IN DELTA
(a)
Average increases in proportion of crop at second picking at 3N
Mean maximum August temperatures (°C)
LATE BOLLS AND APRIL TEMPERATURES IN UPPER EGYPT
(b)
Mean maximum April temperatures (°C)
A.K.

(at 65,000 feddans as against 470,000 in the following year); this cannot be verified for the experiments as no records were kept of the irrigation practice in them in that year. The year 1937 provides the ideal season; March temperatures were almost as favourable as in 1931 but as conditions thereafter were in no way extreme the crop matured and was picked so that the best return from manure and the highest total production were recorded in the experiments for that year. In the years 1934 and 1936 when favourable springs also occurred, the possibilities were reduced by excessive heat in June and August in the former year and in the second half of July in the latter although in neither case was it as severe as in 1931.

The "normal" expectation in the Delta that early-sown cotton will benefit most from fertiliser nitrogen is upset if the weather in May is unsuitable. The amount of benefit was significantly greater with late sown cotton in 1945 and 1946 because it escaped the effects of the heavy and unusual rainstorms that marked that month in these years, culminating in 1946 in a hailstorm in an area to the west and north-west of Cairo; low yielding land as such in the two years gave a significantly better response than high-yielding only in 1945 and only in the northern half of the Delta. The significantly greater response of low yielding land was, on the other hand, a feature of the Delta results as a whole in 1939 and 1941 when late sown cotton again tended to benefit more than early sown cotton, but to an unimportant extent. The average amounts of "soluble" nitrogen present in the soils at thinning were least in 1939 and 1941 so that the conclusion that response in them was conditioned more by deficiency in available soil nitrogen than by anything else seems obvious. The months of May in the Delta in 1939 and 1941 were at the same time the hottest of the sixteen and the exceptional heat may have interfered with the normal development of early sown plants; moreover, the amounts of soluble nitrogen present will themselves be shown to be an expression of the temperatures experienced, tending to be low where these have been high. In 1935 the month of April as well as May was unusually hot and all three relationships between control plot yield, maximum increase and sowing date were quite insignificant in that year.

In Upper Egypt the only marked departure from the normal expectation there that early sown and low yielding cotton will respond best to manure occurred in 1933 when the severe water strain of the hottest month of June of the sixteen caused its entire reversal and return from nitrogen became positively and significantly associated with high control plot yield.

The month of March was coldest in 1938, 1943 and 1945. In 1938 and 1943 the consequent restriction of growth resulted in low control plot yields and returns from manure in the Delta and offering in 1938 a most disconcerting contrast to the excellent season of 1937 which preceded it. In the year 1945 when March temperatures were lowest some compensation was obtained from a warmer May than in the other two years so that the final result was better.

Interactions of Nitrogen

Nitrogen and Method of Sowing

The possibility that the large effects of nitrogen on early bolls obtainable in 1936 and 1937 might be due in part to the fact that the cotton in the experiments for those years was for the first time, with negligible exceptions, dibble-sown, led to the alteration of the design of the experiments in 1938, 1939 and 1940 to include a comparison of the effect of nitrogen on dibble-sown cotton as against cotton sown by the ordinary method.

Dibble-sowing [1] consists essentially in the use of a conical dibble to make a hole one inch deep in pre-watered soil in which are placed not more than five seeds as against the fifteen used in the ordinary way. They are covered with sand, silt or dust and given the usual sowing-watering. The successful use of the method results in a larger number of plants in the best condition and a consequent increased production of early bolls.

The advantage from using the dibble in the three years is summarised in the following table :

Year	Number of experiments	Number in which dibble-sowing had a positive significant effect	Number in which dibble-sowing had a negative significant effect	Number with a significant interaction between nitrogen and method of sowing	Average direct effect (kantars par feddan) : Overall	In experiments showing positive significance
1938	31	15	3	6	0·24	0.51
1939	22	10	1	3	0·26	0·51
1940	36	15	3	10	0·17	0·48

(1) For fuller details *see* : "*Dibble-sowing of Cotton, Method Effect and Profit*" by W. L. Balls and D. S. Gracie. Tech., Bull., No. 229, Ministry of Agriculture, Egypt (1939).

The average yield recorded at each nitrogen level for the three years of the experiments, eliminating season, is as follows (in kantars per feddan) :—

Level of Nitrogen	0N	1N	2N	3N	4N
Dibble-sowing	5·73	6·56	7·01	7·22	7·27
Ordinary sowing	5·52	6·29	6·78	6·99	7·09
Difference in favour of dibble-sowing	0·21	0·27	0·23	0·23	0·18

The dependence of success with the method on the timing of the waterings after the sowing watering has already been discussed under " Irrigation Practice ".

The fact that the increase in yield from the use of the dibble comes with the early bolls is demonstrated from the average figures for the proportion of the crop obtained at the second picking at the different nitrogen levels in the 1939 experiments ; the proportion is consistently lower with dibble-sown cotton :—

Level of Nitrogen	0N	1N	2N	3N	4N
Dibble-sowing	19·8	21·1	23·8	26·4	29·2
Ordinary sowing	21·6	23·2	26·1	28·3	31·1

The average total increases over the control plot yield at each level of nitrogen with dibble-sowing as compared with ordinary sowing in each of the three years are as follows :-

		Average control plot yields	Level of nitrogen			
			0N-1N	0N-2N	0N-3N	0N-4N
1938	Dibble-sowing	5·59	0·63	1·05	1·19	1·20
	Ordinary sowing ..	5·39	0·69	1·01	1·11	1·12
1939	Dibble-sowing	5·81	0·78	1·31	1·38	1·46
	Ordinary sowing ..	5·56	0·71	1·23	1·41	1·50
1940	Dibble-sowing	5·79	1·02	1·45	1·84	1·88
	Ordinary sowing ..	5·60	0·88	1·49	1·87	2·03

The major difference in response to nitrogen is clearly the seasonal one between years which affects the results irrespective of the method of sowing, any differential response arising from the latter being, by contrast, of minor importance. The fact that the cotton in the experiments happened to be dibble-sown for the first time in 1936 and 1937 when unusually large effects from nitrogen on early bolls were possible in the Delta was therefore a pure coincidence; the possibility of the effects existed entirely because of the exceptionally favourable growing weather in the two years. The interaction between nitrogen and method of sowing itself shows variation according to season. In the cold spring of 1938 dibble-sown cotton tended to utilise the nitrogen in the heavier applications more efficiently th n cotton sown in the ordinary way whereas in the more favourable seasons of 1939 and 1940 the increase in efficiency tended to be greatest with the lighter dressings. This is more clearly brought out by a consideration of the average total increases from nitrogen obtained in the experiments in which dibble-sowing exerted a significant positive effect.

		Average control plot yields	Level of nitrogen			
			0N–1N	0N–2N	0N–3N	0N–4N
1938 (15 Exp.)	Dibble-sowing ..	5·59	0·82	1·25	1·37	1·45
	Ordinary sowing	5·20	0·76	1·15	1·19	1·24
1939 (10 Exp.)	Dibble-sowing ..	6·04	0·89	1·55	1·62	1·78
	Ordinary sowing	5·57	0·80	1·40	1·64	1·78
1940 (15 Exp.)	Dibble-sowing ..	5·88	0·99	1·39	1·84	1·88
	Ordinary sowing	5·51	0·73	1·37	1·72	1·78

Particular attention is drawn to the result for 1938. It means that where the success of dibble-sowing has been ensured by timely waterings in an unfavourable season fertiliser nitrogen is more efficiently utilised, the effect being therefore due partly to the method of sowing and partly to better irrigation practice. It has, however, only a limited effect and the major difference, as before, lies between seasons.

NITROGEN AND LOCALITY

The averages given at the bottom of Tables 2 and 3 bring out the difference in response to nitrogen between Upper Egypt and the Delta as a whole. This has been extended by grouping the experiments in the Delta according to their latitudinal distribution. Equal weight is then given to each experiment within each group and equal weight in turn to the average of each group in each season. Averages are given (in Table 11) for the whole period from 1931-1946 and separately for the nine years from 1931 to 1939 and for the seven years 1940-1946. It will be remembered that from 1942 onwards in the latter period the area under cotton was restricted and the crop would therefore tend to be confined to the better land with the possibility of a better response:—

TABLE 11.

Locality	Period	Number of experiments	Kantars per feddan		Maximum increase as per cent of control plot yield
			Average control plot yield	Average maximum increase	
North of 31°00′	**1931–1939**	64	4·43	1·34	30·2
	1940–1946	51	5·21	1·64	31·4
	1931–1946	115	4·76	1·47	30·8
Between 30°45′ and 31°00′	**1931–1939**	50	5·29	1·60	30·2
	1940–1946	39	6·42	1·92	29·9
	1931–1946	89	5·78	1·74	30·1
Between 30°00′ and 30°45′	**1931–1939**	70	5·99	1·70	28·4
	1940–1946	45	6·11	1·81	29·6
	1931–1946	115	6·04	1·74	28·8
Upper Egypt	**1931–1939**	77	6·16	2·01	32·8
	1940–1946	95	5·91	2·60	43·9
	1931–1946	172	6·05	2·27	37·5

With seasonal variation eliminated there is a progressive increase in the first period in both control plot yield and maximum increase from fertiliser as one moves from north to south, as would be expected. In the second period the highest average control plot yield is recorded for the group in the Middle of the Delta but the highest average increase from nitrogen is always obtained in Upper Egypt. The average maximum increase is roughly a constant proportion of the average control plot yield anywhere in the Del a at about thirty per cent; the proportion is consistently higher in Upper Egypt.

Note.—Locality effect in the Delta has been treated of as above solely for the purpose of comparing it with variety effect which is dealt with below. When the "Practical Application" of the results is made later the further subdivision of the experiments according to level of yield and previous crop will show that the increase obtainable is very far from being a constant proportion of the control plot yiel whether in Lower or Upper Egypt.

Nitrogen and Variety

One of the measures taken to minimise the effect of the pink bollworm was the introducti n of earlier and higher yielding varieties. These may, therefore, as with closer spacing, have created a greater need for nitrogen now as compared with thirty-five years ago but again the results of the experiments can give no measure of it. Giza 7 was the first of these new varieties and already accounted for eleven out of fifteen experiments in the Delta in 1931, the first year of the experiments, when the return from nitrogen was lowest, while Sakel was represented only once.

The classification of the experiments by variety is given in Table 12.

With the exception of Ashmouni the distribution of these varieties with time is very unequal so that results are not really comparable. Karnak was only grown in the second half of the period and Giza 7 mainly in the first. Sakel made its last appearance in one experiment in 1937 and Sakaa 4 in two in 1940. The figures for yields presented in Table 13 have, therefore been obtained by the straightforward averaging of the results of individual experiments without regard to season.

TABLE 12.— THE NUMBER OF EXPERIMENTS WITH VARIETIES BY YEARS

Year	Sakel and Sakha 7	Sakha 4	Giza 7	Karnak	Wafeer	Menoufi	Zagora	Ashmouni	Others	Total Number of experiments
1931	1	—	11	—	—	—	1	6	4	23
1932	7	7	7	—	—	—	4	14	3	42
1933	4	1	5	—	—	—	5	8	6	29
1934	7	—	10	—	—	—	1	6	1	25
1935	4	3	10	—	1	—	3	2	2	25
1936	3	2	11	—	6	—	3	7	3	35
1937	1	3	7	—	3	—	7	8	—	29
1938	—	2	12	—	7	—	1	8	1	31
1939	—	2	9	1	4	—	1	5	—	22
1940	—	2	4	3	3	—	8	14	2	36
1941	—	—	5	8	—	1	6	14	1	35
1942	—	—	1	10	—	2	2	13	—	28
1943	—	—	1	15	—	2	—	13	2	33
1944	—	—	1	10	—	3	—	14	2	30
1945	—	—	1	11	—	6	—	14	2	34
1946	—	—	—	13	—	7	—	12	2	34
TOTALS ...	27	22	95	71	24	21	42	158	31	491

TABLE 13.—NITROGEN AND VARIETY

(Kantars per feddan)

Variety	Number of experiments	Average control plot yield	Average maximum increase	Maximum increase as percentage of control plot yield
Sakel and Sakha 7 ...	27	3.93	1.14	29.0
Sakha 4	22	4.66	1.29	27.6
Giza 7	95	5.43	1.84	33.8
Karnak	71	5.83	1.80	30.8
Menoufi	21	6.41	1.79	27.9
Wafeer	24	6.29	1.96	31.1
Zagora..	42	6.38	1.77	27.7
Ashmouni	158	6.00	2.34	39.0

There is a similar, but not such a close, association between control plot yield and maximum increase as with locality, the higher yielding varieties responding more to manure. Variety is, however, inextricably confounded wi h locality and had the varietal distribution with time been more equal so that seasonal variation could be eliminated, it is probable that the same conclusion would have been come to as for locality. Sakel and Sakha 7 have given the lowest average control plot yield and response to nitrogen but this may merely be an expression of the fact that they wer grown in the north and in a limited range of season. Response, whether expressed as kantars per feddan or as a proportion of the control plot yield, is greatest in Upper Egypt (Variety Ashmouni), but the suggestion offered by the figures for the Delta that Giza 7 was a variety giving a disproportionately higher response than the others or that Zagora and Menoufi respond less is not necessarily the case. On the average of the figures the maximum extent to which yield can be affected by nitrogen in the Delta is again about thirty per cent.

Nitrogen and the Previous Crop

Cotton is chiefly grown after maize, berseem catch crop and rice. The experiments from 1932-1946 (the previ us crop was rarely recorded in the 1931 experiments) have been grouped from this point of view and averaged, giving equal weight to each season :—

Previous crop	Number of experiments	Kantars per feddan: Average control plot yield	Average maximum increase	Averags total production	Average maximum increase as percentage of contiol plot yield
Maize	226	6·03	2·10	8·13	34·8
Berseem catch crop	102	5·77	1·73	7·50	29·9
Rice	65	4·61	1·73	6·34	37·5

Total production is lower after berseem than after maize and lowest after rice, while response to nitrogen is proportionately greatest after rice and least after berseem. The differences are real and are due to differences in locality (rice), sowing date (berseem) and the available nitrogen present in the soil (rice); they are more fully analysed below under " Practical Application ".

Available Soil Nitrogen

To obtain an estimate of the nitrogen available two separate determinations are made in the laboratory on the soil samples taken from the experiments. The first is a measure of what is called "soluble" (ammoniacal and nitrate) nitrogen and the second measures the "hydrolysable" nitrogen. The former is what is extracted by leaching the air dry soil with normal sodium chloride solution and the latter what is brought into solution by heating the soil under standard conditions with dilute sulphuric acid. The hydrolysable nitrogen is regarded as a measure of the mobilizable nitrogen present in addition to the ammoniacal and nitrate nitrogen. The two fractions together form the " available " nitrogen.

The soils of the experiments were at first (1935-1937) sampled only at sowing time and there was complete failure to demonstrate any correspondence between the estimates of available nitrogen made in the laboratory and the yields recorded in the field. In 1938 and 1939 soil samples were taken at the two times of sowing and thinning and from 1940 onwards only at the time of thinning. (Thinning takes place about a month and a half after sowing and it is then that nitrogenous fertilisers are applied. The actual sampling

TABLE 14.—RELATIONSHIP BETWEEN AVAILABLE NITROGEN AT THINNING AND YIELD

Year	Total Number of experiments	Number Sampled	Total correlations between control plot yields and soluble nitrogen in:				Total correlation between maximum increases and hydrolysable nitrogen in:		
			C.S.S.	C.S.S. +A	C.S.S. + profile	Profile	C.S.S.	C.S.S. + A + B	C.S.S. + profile
1938	31	30	+ ·58 (28)	+ ·61 (28)	+ ·60 (27)	+ ·34 (27)		— ·25 (30)	
1939	22	21	+ ·65 (21)	+ ·62 (21)	+ ·66 (21)	+ ·52 (21)	— ·54 (20)	— ·62 (20)	
1940	36	36	+ ·30 (35)		+ ·29 (34)	+ ·09 (34)		— ·37 (36)	— ·30 (35)
1941	35	35	+ ·28 (35)		+ ·23 (35)	+ ·21 (33)		— ·22 (34)	— ·16 (34)
1942 *	28	28							
1943	33	31	+ ·07 (29)		+ ·26 (25)	+ ·20 (27)		— ·11 (31)	— ·02 (30)
1944	30	27	+ ·39 (27)		+ ·28 (27)	+ ·41 (26)	— ·28 (26)	— ·19 (27)	— ·20 (26)
1945	34	32	+ ·40 (30)		+ ·53 (30)	+ ·38 (30)		— ·29 (32)	
1946	34	33	+ ·02 (31)		+ ·03 (31)	+ ·01 (31)†		+ ·04 (33)	

* The soluble and hydrolysable nitrogen were not separately determined.

† This correlation becomes significant at R= + ·50 for twenty-eight experiments.

Note.— C.S.S. = Composite Surface Sample from control plots. A = 0–25 cm. layer. B = 25–50 cm. layer Profile = Total depth to one metre. The number in brackets after a coefficient is the number of experiments on which it is based.

dates will therefore again vary according to locality and season but they will roughly all be at the same stage of development of the plant.) The available nitrogen present at sowing in 1938 and 1939 bore, as in the previous three years, no relationship to the yields recorded but some success has been obtained with the estimates of available nitrogen made on soil samples taken at thinning. It is summarised in Table 14 and illustrated in Fig. 11.

The table shows that the soluble nitrogen at thinning is positively correlated with control plot yield and the hydrolysable negatively with maximum increase from nitrogen, the former relationship being consistently more pronounced than the latter.

The amount of available nitrogen present and the extent to which the crop depends on it is just as much subject to seasonal influence as is the efficiency of fertiliser nitrogen. This is not necessarily reflected in the values of the associations given in Table 14 but is brought out by the average figures for available nitrogen present at thinning in the various years and especially by the amounts of available nitrogen respectively present at sowing and at thinning in 1938 and 1939. These two seasons were contrasted in that the months of March and April were colder in 1938 than in 1939 (*see* Table 10).

TABLE 15.—AVAILABLE SOIL NITROGEN AT SOWING AND AT THINNING IN THE 1938 AND 1939 EXPERIMENTS

(Parts per million)

Depth of layer (cm.)	At Sowing				At Thinning			
	1938		1939		1938		1939	
	Av. of 30 expts.		Av. of 21 expts.		Av. of 30 expts.		Av. of 21 expts.	
	NH_3-N + NO_3-N	H.N.	NH_3-H + NO_3-N	H.N.	NH_3-N + NO_3-N	H.N.	NH_3-N + NO_3-N	H.N.
C.S.S.	18·6	19·4	22·6	18·8	69·3	22·1	37·0	19·6
0– 25	18·2	18·8	14·0	17·6	23·6	18·6	14·4	18·4
25– 50	7·0	11·4	6·5	12·0	11·1	12·8	8·5	12·2
50– 75	5·7	9·4	5·5	10·6	8·1	10·6	6·3	11·0
75–100	5·6	8·5	5·2	9·4	7·2	10·0	5·3	9·9
TOTALS ...	55·1	67·5	53·8	68·4	119·3	74·1	71·5	71·1

Note.— C.S.S. = Composite Surface Sample. H.N. = Hydrolysable Nitrogen. The figures for a 25 cm. layer may roughly be regarded as kilos per feddan.

TABLE 16.—AVAILABLE NITROGEN AT THINNING IN THE COTTON EXPERIMENTS FROM 1940 to 1946

(*Parts per million*)

Depth of layer (cm.)	1940 — (36 expts.)			1941 — (35 expts.)			1942 — (28 expts.)			1943 — (31 expts.)		
	NH_3—N + NO_3—N	H.N.	TOTAL	NH_3—N + NO_3—N	H.N.	TOTAL	NH_3—N + NO_3—N	H.N.	TOTAL	NH_3—N + NO_3—N	H.N.	TOTAL
C.S.S.	41·5	18·7	60·2	49·5	15·0	64.5	—	—	83·2	73·5	13·4	86·9
0– 25	23·9	15·7	39·6	16·7	14·2	30.9	—	—	33·1	31·7	14·0	45·7
25– 50	10·8	11·8	22·6	13·1	9·1	22.2	—	—	20·9	20·3	11·6	31·9
50– 75	9·7	10·6	20·3	9·6	7·8	17.4	—	—	16·4	14·4	10·5	24·9
75–100	15·2	9·2	24·4	9·9	7·0	16.9	—	—	15·4	19·7	9·9	29·6
TOTALS ...	101·1	66·0	167·1	98·8	53·1	151·9	—	—	169·0	159·6	59·4	219·0

TABLE 16 (*contd.*)

Dehth of layer (cm.)	1944 — (27 expts.)			1945 — (32 expts.)			1946 — (34 expts.)		
	NH_3—N + NO_3—N	H.N.	TOTAL	NH_3—N + NO_3—N	H.N.	TOTAL	NH_3—N + NO_3—N	H.N.	TOTAL
C.S.S.	59·9	17·2	77·1	66·8	17·7	84·5	48·6	19·1	67·7
0– 25	18·8	17·4	36·2	23·2	17·0	40·2	27·5	17·3	44·8
25– 50	12·2	13·6	25·8	16·5	13·1	29·6	19·7	12·5	32·2
50– 75	9·7	10·9	20·6	12·2	11·0	23·2	12·4	10·9	23·3
75–100	9·4	10·5	19·9	15·5	9·6	25·1	12·1	10·1	22·2
TOTALS ...	110·0	69·6	179·6	134·2	68·4	202·6	120·3	69·9	190·2

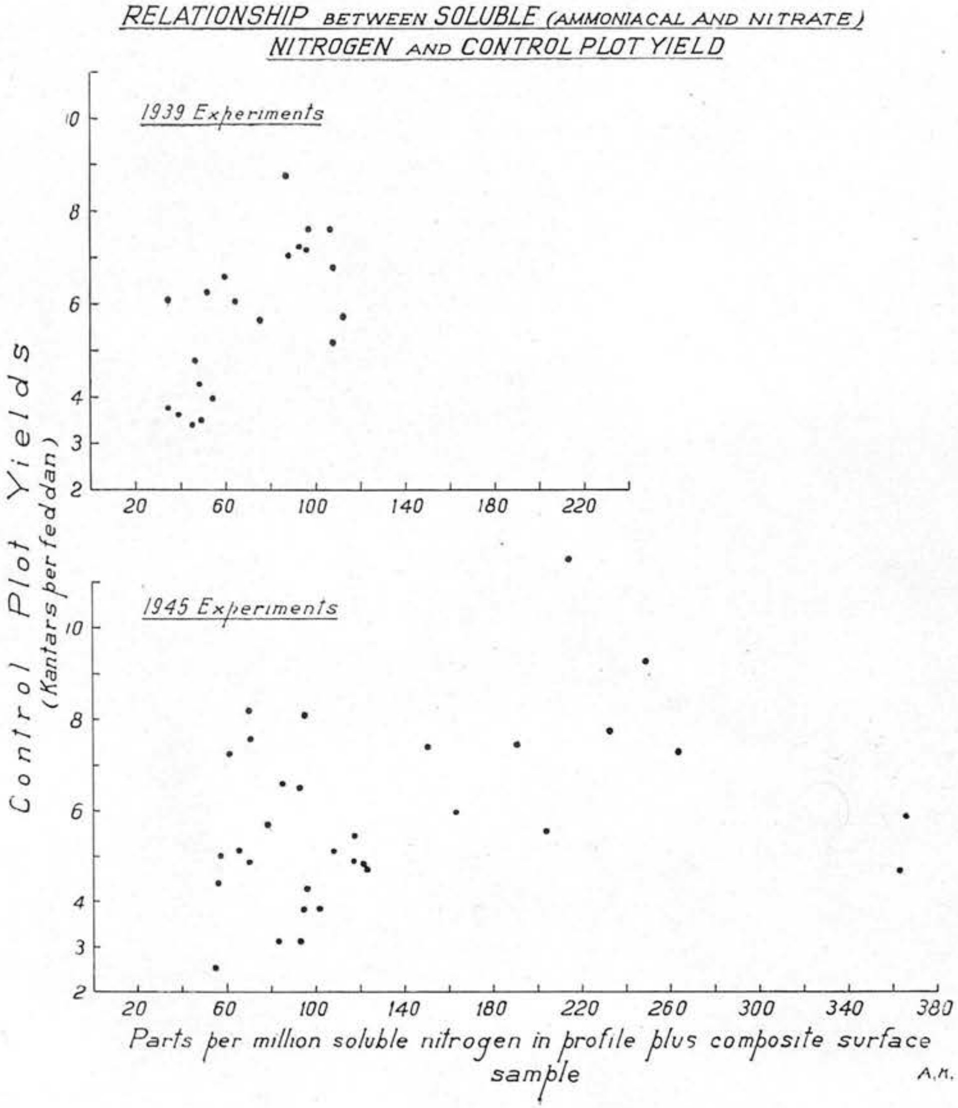
The average content of available nitrogen at sowing time was roughly the same in both years but it became very dissimilar a month and a half later. The so s in the 1938 experiments, after the colder spring, contained very much larger amounts of soluble (ammoniacal and nitrate) nitrogen than in 1939,all layers of the profiles being affected.

The average figures for available nitrogen at thinning only for the remaining years from 1940-1946 are given in Table 16.

If the average parts per milli n of soluble nitrogen contained at thinning in the profile plus composite surface sample of Tables 15 and 16 are plotted against the mean maximum April temperatures for the Delta (those for Upper Egypt would do equally well) of Table 10*b*, as in Fig 12*a*, a strong negative relationship is evident, more nitrogen being present after the colder springs; there is a similar, but not such a close, connection with the mean maximum temperatures for the month of March. The fact that all layers of the profiles are involved is shown by Fig 12*b* where the average soluble nitrogen contained in the bottom fifty centimetres is plotted against the mean maximum April temperatures. As distinct from the positive effect found in individual experiments, there is of course, no particular relation between these average values for soluble nitrogen and average control plot yield.

The meaning of a given amount of soluble nitrogen for control plot yield will therefore, vary according to season; it is illustrated in F g 11 from the 1939 and 1945 experiments. Not only is the soluble nitrogen higher on the average after the cold spring of 1945 than the warmer one of 1939 (the average control plot yields are not very different) but the range of values encountered is very much greater. In calculating the correlation coefficients presented in Table 14 the more extreme of these values have been dropped. Fig 11 shows that the two so dropped for 1945 contained 360 parts per million or more of soluble nitrogen in the profile plus composite surface sample; but even these large amounts have been exceeded in thirteen experiments in other years, six of them being in 1943 when the month of April was coldest. In some of these experiments only the composite surface sample is involved and in others the whole profile Such large amounts of "soluble" nitrogen are very much greater than can be utilised by the crop so that, in spite of their more frequent occurrence in the colder seasons when the nitrogen uptake of the crop will have been less, they raise the question of what category of nitrogen, in addition to nitrate, is actually being extracted by the salt solution used in their estimation. In the fifteen experiments containing the exceptionally large amounts of soluble nitrogen the maximum increase from fertiliser nitrogen ranged from 0·28 of a kantar up to 5·95 kantars per feddan and averaged 2·25 kantars.

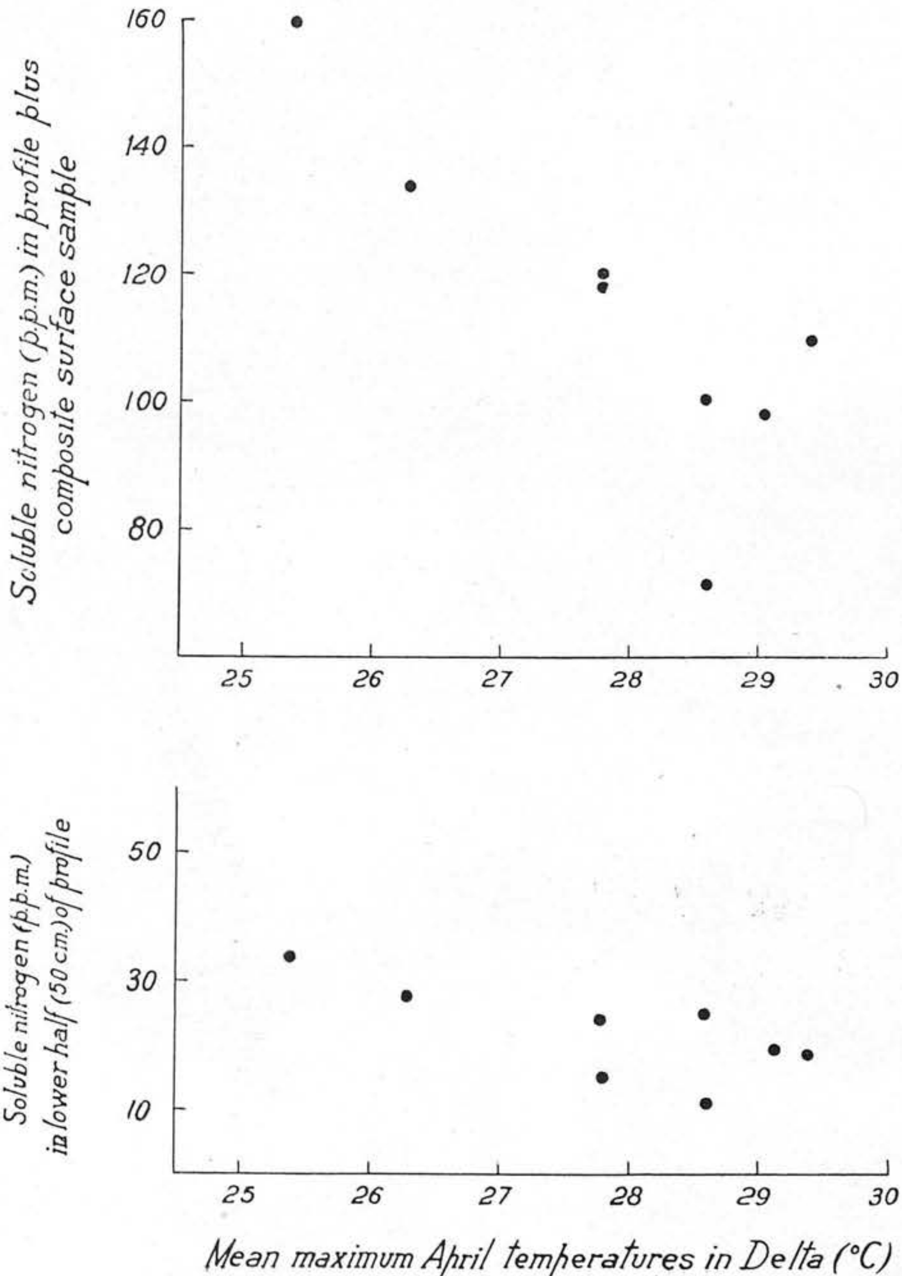
Fig. 11



RELATIONSHIP BETWEEN SOLUBLE (AMMONIACAL AND NITRATE) NITROGEN AND CONTROL PLOT YIELD
1939 Experiments
1945 Experiments
Control Plot Yields
(Kantars per feddan)
2
3
4
6
8
10
20
60
100
140
180
220
260
300
340
380
Parts per million soluble nitrogen in profile plus composite surface sample
A.K.

Fig. 12

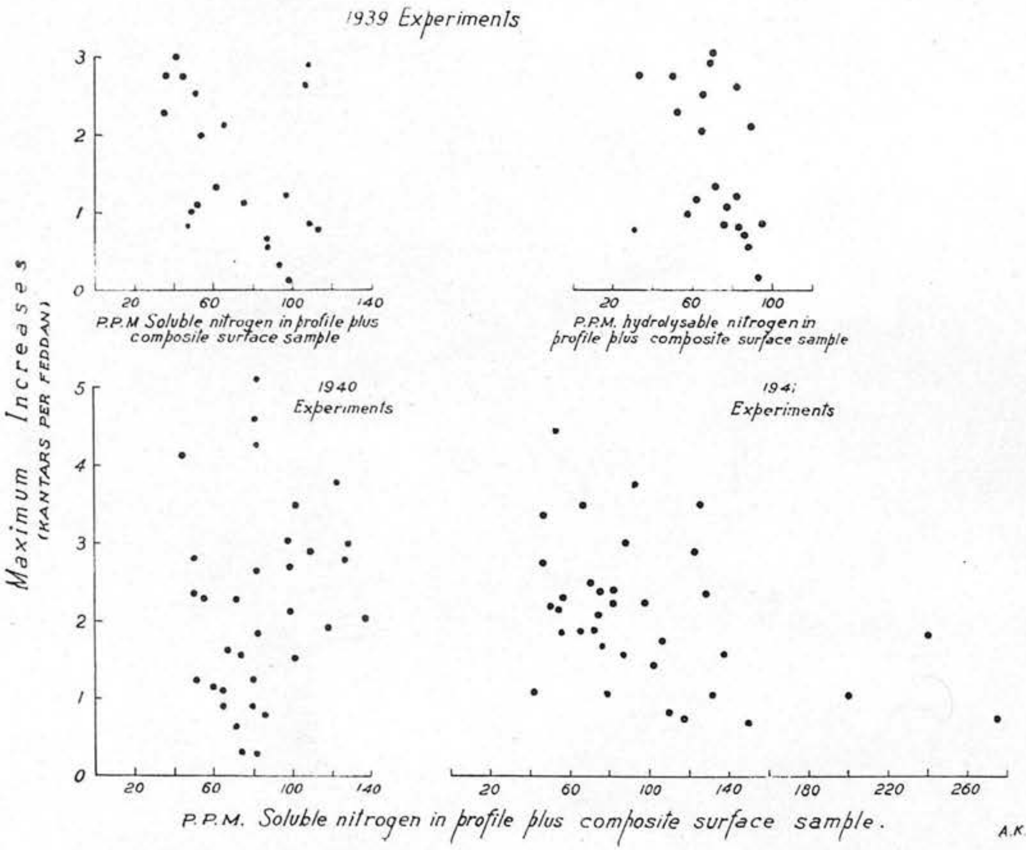
RELATIONSHIP BETWEEN APRIL TEMPERATURES AND SOLUBLE NITROGEN AT THINNING



A K.

Fig. 13

RELATIONSHIP BETWEEN AVAILABLE NITROGEN AND MAXIMUM INCREASES



Taking the experiments as a whole the result can be considered to have been seriously influenced by deficiency in available soil nitrogen only in the two years 1939 and 1941 when the average soluble nitrogen was lowest. It is in these two years that there were significant negative correlations in the Delta between maximum increase and control plot yield so that low yielding land responded better in Lower as well as in Upper Egypt. Fig 13 shows that the maximum increases from nitrogen were inversely related to the soluble nitrogen in 1939 and 1941 but were scarcely connected at all in the other years of which 1940 may be regarded as typical ; it is in 1939, when the average soluble nitrogen present was least, that the hydrolysable fraction of the available nitrogen assumes its greatest importance. Deficiency in available soil nitrogen following on high April temperatures may not have been the only factor determining the result in 1939 and 1941 ; as has already been pointed out (p. 27) the months of May in these two years were easily the warmest of the series and the exceptional heat may have interfered with the normal development of forward plants.

The separation of the results for Upper and Lower Egypt does not add to the information already given ; the relationship between soluble nitrogen and April temperatures is actually weaker for the regions treated separately than for the experiments as a whole. Eleven of the fifteen experiments showing the very large amounts of soluble nitrogen were in Upper Egypt, four of them being for 1943, the year in which the average return from nitrogen there was greatest.

A very useful subdivision that can be made is that of the experiments conducted after rice. There were twenty-seven of these in seven years — there were none at all in 1944 and in 1942 the soluble and hydrolysable nitrogen were not separately estimated. The average amounts of available nitrogen, eliminating seasonal effect, in the twenty-seven are compared with similar averages for all experiments in Table 17.

TABLE 17.—AVERAGE (ELIMINATING SEASON) AVAILABLE NITROGEN IN EXPERIMENTS AFTER RICE AS COMPARED WITH ALL EXPERIMENTS

(Parts per million)

Depth of layer (cm.)	Experiments after rice			All experiments		
	Soluble nitrogen	Hydrolysable nitrogen	Available nitrogen	Soluble nitrogen	Hydrolysable nitrogen	Available nitrogen
C.S.S.	45·5	18.9	64·4	55·7	17·7	73·4
A	18·8	16.8	35·6	22·4	16·6	39·0
B	11·6	12.4	24·0	14·0	12·0	26·0
C	7·7	9.9	17·6	10·3	10·4	20·7
D	6·2	9.3	15·5	11·8	9·5	26·8
TOTALS ...	89·8	67.3	157·1	114·2	66·2	185·9

The greater degree of response of cotton grown after rice as compared with other crops is therefore associated with a lower avail ble nitrogen in the soil ; the difference occurs mainly in the soluble nitrogen fraction and the subsoil layers are proportionately more affected.

There is a continuous variation in the state of the organic matter and nitrogen present. It has already been seen that the estimates of available nitrogen on soil samples taken at the time of sowing bear no relationship to the recorded yields, but the best illustration of the practical bearing of the changes that take place is found in the experiments on sharaqi (fallow) land. The effect of a period of bare fallow or drying is to increase the amount of soluble (ammoniacal and nitrate) nitrogen and the experiments on sharaqi land[1] were designed to show that if bacterial activity (by irrigation) is reintroduced too soon before the planting of the succeeding crop a considerable part of the benefit is lost. The results of one such experiment conducted on cotton in Upper Egypt in 1934 to measure the nitrogen loss on land which had received a pre-ploughing watering as compared with land ploughed dry are given in illustration :—

Sharaqi Experiment with Cotton at Qous (1934)

Treatments	Watered before ploughing		Ploughed dry		Date of sowing	Dates of picking
	Yield in kantars per feddan	% of crop at 2nd picking	Yield in kantars per feddan	% of crop at 2nd picking		
No manure	4·85	5·8	5·29	7·3		
1N	5·99	5·6	6·64	8·5	22/3	1/9and 17/9
2N	6·73	6·6	7·18	9·5		
3N	7·31	6·8	7·96	11·9		

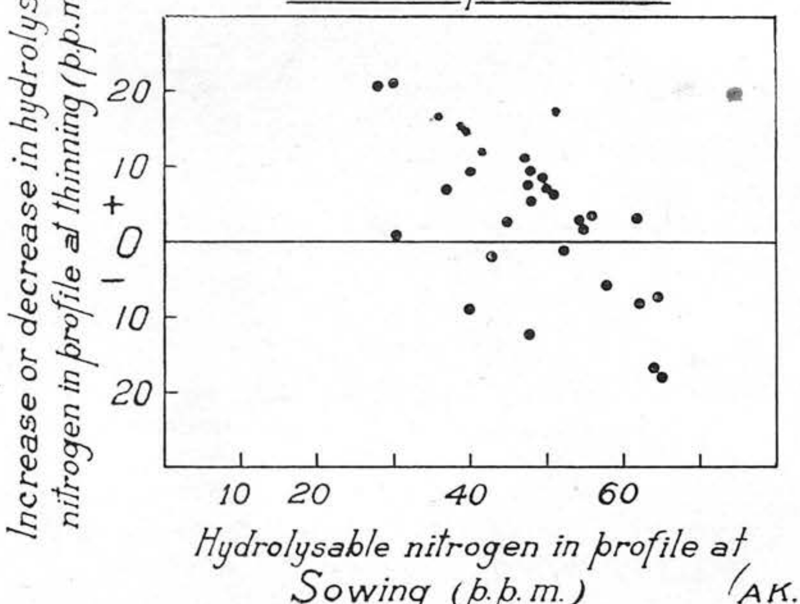
The ploughing watering given about a month before sowing caused a reduction in the nitrogen available which is reflected in lowered yields and in a consistently smaller proportion of the crop at the second picking ; even at 3N the cotton on land so treated shows no

(1) The experiments on sharaqi land are reported in full in : "*The Quantity, Distribution and Composition of the Organic Matter and Available Nitrogen in Egyptian Soils*", by David S. Gracie and Fahmy Khalil. Techical Bulletin No. 222, Ministry of Agriculture, Egypt (1939).

Fig. 14

INCREASE OR DECREASE IN HYDROLYSABLE NITROGEN AT THINNING COMPARED WITH THAT PRESENT AT SOWING

1938 Experiments



sign of overtaking the cotton on land ploughed dry in either respect. The loss is the greater the richer the land ; that on which the above experiment was carried out was not particularly well supplied. The " loss " is not a permanent one ; it occurs through some of the soluble nitrogen being converted by bacterial action to more unavailable forms which will only slowly again become available. The lowered soluble nitrogen in the soils of the experiments after rice may similarly be the result of their treatment the previ us summer.

Similar considerations apply to the amount of hydrolysable nitrogen that may be prese t at any given time. Fig 14 shows that, after the cold spring of 1938, there was a marked inverse correlation between the hydrolysable nitrogen in the profile at sowing and the increase or decrease that took place by the time of thinning. The relationship did not exist for the 1939 experiments when temperatures were higher, the soluble nitrogen at thinning much lower and the connection between maxim m increase and the hydrolysable nitrogen significa t.

Further investigation along the lines indicated above will be necessary to obtain a dependable estimate of the available nitrogen. And any such estimate must in any case be qualified in addition by some expression for the physical properties of the soil if it is to be of real value. The data so far accumulated on this latter aspect are too few to permit of useful discussion and until this is remedied it will be impossible to say how far the dependence of control plot yield on soluble nitrogen is purely a nitrogen effect or is in addition the reflection of more deep-seated changes (deterioration) of which a reduced organic matter status may be one of the symptoms. (1)

From the more immediately practical point of view these observations on soil nitrogen mean that the question of time of application of nitrogenous ferti isers should perhaps receive f rther attenti n. The application of nitrogenous fertiliser at the time of sowing results in a serious loss in efficiency similar to what happens to the available nitrogen in sharaqi land if it is watered too soon before the planting of the succeeding crop. What is suggested here is that it might be good practice to give a small part f the nitrogenous fertiliser at the watering before the thinning watering in cases where the soluble nitrogen can be expected to be below the average, as with the experiments after rice. Where the deficiency arises as the result of the temperatures experienced in spring, as in 1939 and 1941, it is more difficult to advise it since there must always be the element in that case of being wiser after the event.

(1) *Loc. cit.* p. 9

Effect of Superphosphate

The effect of superphosphate for the fourteen years from 1933 to 1946 is summarised in Table 18 :—

TABLE 18.—EFFECT OF SUPERPHOSPHATE

Year	Number or experiments	Number of experiments showing a significant.			Average direct effect (kantars per feddan)
		Positive response	Negative response	Interaction between nitrogen and superphosphate	
1933	29	4	1	1	0·24
1934	25	7	—	2	0·19
1935	25	7	—	2	0·21
1936	35	9	1	3	0·13
1937	29	4	1	1	0·13
1938	31	10	1	4	0·14
1939	22	10	—	4	0·18
1940	36	13	2	10	0·17
1941	35	6	—	4	0·19
1942	28	4		4	0·15
1943	33	7	—	2	0·22
1944	30	7	3	5	0·08
1945	34	8		2	0·16
1946	34	14	1	2	0·32
Totals and Average ...	426	110 or 25·8 %	10	46	0·18

The degree of significant positive response (25·8 per cent) as well as the average yield effect (0·18 of a kantar per feddan) are of course very much less than those obtained with nitrogen ; the fact that a significant negative response can be experienced must also be taken into consideration.

Estimations of available phosphoric acid by the Aspergillus niger method have been made on the soil samples from one hundred and nineteen experiments conducted in the four years 1935-1938. This biochemical method for estimating available phosphoric acid consists essentially in growing the fungus under standard conditions in a culture solution containing two per cent citric acid in which the only source of phosphorus is five grams of the soil under investigation.

At the end of the incubation period the tough mat of mycelium is removed, washed, oven-dried and weighed. The determination is made in quadruplicate so that the figures reported are grams mycelium per twenty grams soil. Full details of experience with the method and of the results obtained by its use are given in a separate bulletin.(1)

In that bulletin it is shown that the available phosphoric acid in perennially irrigated soils decreases significantly with depth and that, while the subsoils are in process of being reduced to a state of uniform exhaustion, the supply in the surface layers is being more or less maintained by the additions being made to them. Variability in the subsoil has therefore naturally become very significantly less than at the surface, although the actual amounts that may be present in the lower layers of the individual profiles are still very variable. Significant positive response to superphosphate in the experiments may occur where that amount sinks below a certain minimum value anywhere within the total depth of one metre. This may not happen until the bottom layer of the profile is reached but generally occurs above it and may (exceptionally) begin at the very surface. The minimum value is about 2·00 g. mycelium per 20 g. soil in the Aspergillus method, corresponding to about 30 mg. phosphoric acid per cent. The average weights of mycelium obtained in cases of significant positive response are compared in Table 19 with the averages for experiments in Upper Egypt and the Delta respectively which showed no such response :

TABLE 19.—COTTON EXPERIMENTS 1935-1938

(119 experiments)

(*Grams mycelium per 20 g. soil in Aspergillus niger test*)

Depth of layer (cm.)	Average of thirty experiments showing significant positive response	Average of fifty experiments in Delta showing no significant response	Average of thirty-two experiments in Upper Egypt showing no significant response
C.S.S.	2·93	3·24	3·62
0–25	2.71	3·09	3·43
25 50	2·19	2·62	2·86
50-75	1·87	2·41	2·64
75–100	1·76	2·36	2·49

(1) "*The Total and Available Phosphoric Acid in Egyptian Soils and the Effect of Superphosphate on the Main Agricultural Crops*", by D. S. GRACIE and F. KHALIL, Technical Bulletin No. 251, Ministry of Agriculture, Egypt (1948).

Of the thirty experiments which gave a significant positive response there was one in which all layers of the profile were very well supplied with available phosphoric acid but in addition t the remaining twenty-nine there were a further thirty (with no significant response) where the subsoils were deficient according to the criterion given above, *i.e.* they contained a layer or layers yielding less than 2 g. of mycelium per 20 g. soil in the Aspergillus niger test. If however stat stical significance is disregarded and an increase of one-tenth of a kantar or more arbitrarily taken as real there will be forty-one additional experiments in which superphosphate had a beneficial action. Twenty-seven out of the further thirty experiments mentioned as having deficient subsoils are included in these additional forty-one, the average increase in yield in them being 0·22 of a kantar per feddan. For the remain ng fourteen, with their richer subsoils, the mean effect was 0·16 of a kantar which is less than the average (0·18) for the experiments as a whole. There remain three experiments with subsoils deficient by the Aspergillus niger method where the response to superphosphate was negligibly small or slightly negative.

The average mycelium weights given in Table 19 show that the surface layers of profiles from experiments giving a significant positive response are poorer in available phosphoric acid than the surface layers of profiles from experiments in the Delta showing no significant response ; the difference is not so great as between the subsoils, but it is still considerable. With the very considerably greater varia ion of surface as compared with subsoil it is clear that it would be impossible to determine whether a soil is deficient in available phosphoric acid for cotton merely by an examination of the surface layer, except of course in the rare cases where that surface layer itself has become deficient. The Aspergillus method, used as described above, while giving satisfactory agreement with the recorded yields, would be too laborious for use on a large scale. When all subsoils have become uniformly exhausted, as they eventually will, this difficulty will no longer obtain.

Interactions of Superphosphate

Superphosphate and Variety

The fact that it is deficiency in the sub-surface layers which largely decides whether cotton will respond to superphosphate or not makes an examination of the results of the experiments from the point of view of variety of interest. It may be supposed that the deeper-rooted varieties such as Sakel, Sakha 4, Malaki, Karnak and Giza 7 will have responded more than the shallower-rooted ones such as Zagora and Ashmouni. Table 20 gives an analysis of the results of the experiments from this point of view.

TABLE 20.—COTTON VARIETIES AND RESPONSE TO SUPERPHOSPHATE, 1933-1946

Variety	Number of experiments	Number showing a significant positive response	Percentage showing a significant positive response	Average yield effect (kantars per feddan)
Sakel and Sakha 7 ...	19	7	—	0·37 (0·24 for 18)
Sakha 4	15	6	—	0·13
Giza 7	77	29	37·6	0·26
Wafeer	24	8	33·3	0·09
Karnak	70	17	24·3	0·20
Menoufi	22	5	22·7	0·17
Zagora	38	6	15·7	0.13
Ashmouni	136	29	21·3	0·15

It has already been pointed out that the distribution of these varieties (Ashmouni excepted) in time is very unequal so that seasonal variation (it is discussed below) cannot be eliminated in making comparisons. The varieties that have shown the greatest average response are Sakel, Giza 7, and Karnak, which are deep-rooted varieties The fifth of a kantar given on the average by Karnak would, with normal times and prices, be well worth considerat on.

SUPERPHOSPHATE AND THE PREVIOUS CROP

The experiments have been analysed from the point of view of degree of response obtained after various crops. The figures in Table 21 show that there is very little in it.

TABLE 21.—RESPONSE TO SUPERPHOSPHATE OF COTTON FOLLOWING VARIOUS CROPS

Previous crop	Maize	Berseem	Rice
Number of experiments	206	94	65
Number responding significantly ...	59	25	18
Percentage responding significantly...	28·6	26·5	27·6
Average yield effect (kantars per Feddan)	0·19	0·19	0·20

SUPERPHOSPHATE AND NITROGEN

Taking the experiments as a whole there is no consistent interaction between nitrogen and superphosphate where the direct effect from the latter is small. This can be illustrated from the 1937 experiments :—

1937 EXPERIMENTS

(Average of twenty-nine experiments)

(Kantars per feddan)

	0N	1N	2N	3N	4N	Direct effect of 2P
2P	7.02	8·16	8·88	9·37	9·71	
0P	6.93	7·93	8·90	9·25	9·48	
Difference	0.09	0·23	—0·02	0·12	0·23	0·13

Where the average effect from superphosphate is greater, as in 1946, interaction appears and means that the efficiency of the larger dressings of nitrogen is increased.

1946 EXPERIMENTS

(Average of thirty-four experiments)

(*Kantars per feddan*)

	0N	1N	2N	3N	4N	Direct effect of 2P
2P	6·09	7·02	7·69	7·91	8·09	
0P	5·82	6·75	7·35	7·57	7·69	
Difference	0·27	0·27	0·34	0·34	0·40	0·32

If these 1946 experiments are split up into the twenty-one for the Delta and the thirteen for Upper Egypt and separately averaged, the interaction is seen to be associated with the higher Delta response ; it is little in evidence in Upper Egypt where the direct effect from superphosphate is lower :—

1946 DELTA EXPERIMENTS

(Average of twenty-one experiments)

(*Kantars per feddan*)

	0N	1N	2N	3N	4N	Direct effect of 2P
2P	5·51	6·46	7·01	7·22	7·27	
0P	5·17	6·15	6·58	6·69	6·77	
Difference ...	0·34	0·31	0·43	0·53	0·50	0·41

1946 UPPER EGYPT EXPERIMENTS

(Average of thirteen experiments)

(*Kantars per feddan*)

	0N	1N	2N	3N	4N	Direct effect of 2P
2P	7·02	7·92	8·77	9·04	9·41	
0P	6·88	7·72	8·59	8·99	9·18	
Difference ...	0·14	0·20	0·18	0·05	0·23	0·16

In experiments in which superphosphate has exerted a significant positive action, and the yield effects are therefore greater than the average, the extent of the effect again increases as one moves from the the lower to the higher nitrogen levels :—

1939 EXPERIMENTS

(Average of ten showing a significant positive response to superphosphate)

(Kantars per feddan)

	0N	1N	2N	3N	4N	Direct effect of 2P
2P	5·69	6·62	7·26	7·52	7·71	
0P	5·41	6·30	6·86	7·11	7·14	
Difference ...	0·28	0·32	0·40	0·41	0·57	

Since the effect of superphosphate in the experiments has been small, interaction with nitrogen has on the whole been negligible ; as the subsoils of perennial land become increasingly exhausted in available phosphoric acid and the need for superphosphate increases, the interaction will also become of greater importance.

SUPERPHOSPHATE NITROGEN AND TEMPERATURE

The influence of temperature on yield returns from superphosphate is inconsiderable but it is interesting because it acts in a manner directly contrary to what has been shown for nitrogen. Fig 15 shows that there tends to be an inverse relationship between mean minimum April temperatures and the average effect of phosphate. It would scarcely be worth mentioning were it not confirmed by the strong association between minimum January and February temperatures and the response to superphosphate of wheat*, and the fact that it may become of greater importance in the future. With average benefit thus tending to be greater in cold weather depressant effects on the other hand can occur on soils rich in available phosphoric acid where nitrogen supply and temperature combined favour rapid vegetative growth.

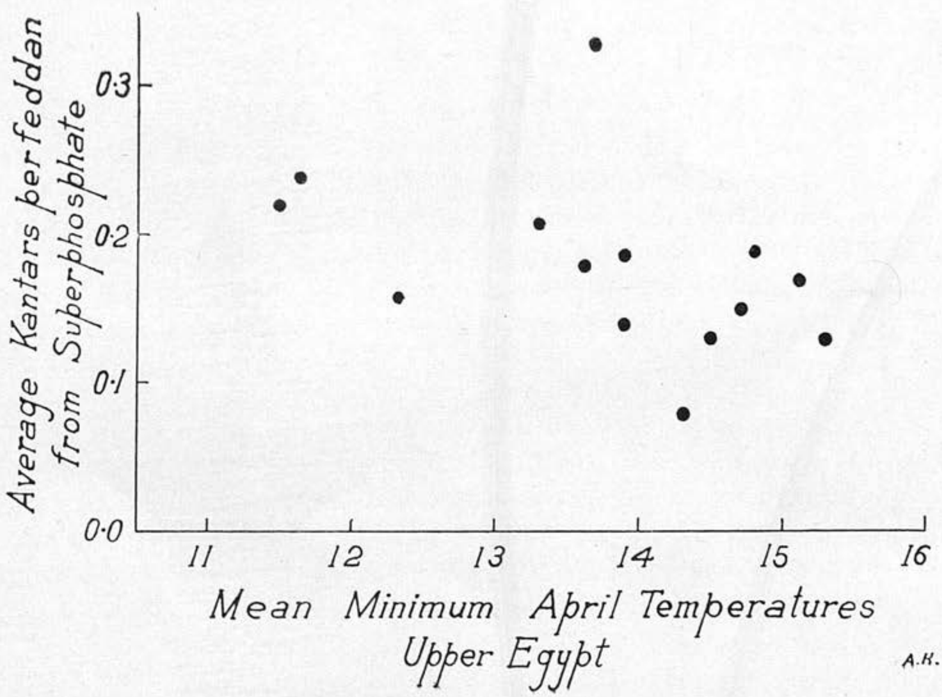
(*) *Loc. cit.* p. 45.

The extent of the response of wheat to superphosphate is greater than with cotton at about six per cent as against three per cent.

Fig. 15

ALL EXPERIMENTS
1933 - 1946

RELATIONSHIP BETWEEN TEMPERATURE AND YIELD EFFECTS FROM SUPERPHOSPHATE.



The nature of these depressant effects receives its best illustration from a few exceptional results [1] in the 1938–1940 experiments which included a comparison of the effect of nitrogen on dibble-sown cotton as c mpared with cotton sown in the ordinary way. In some of these exceptional experiments an unsatisfactory time-scale of the watering intervals may have influenced the result ; the yields recorded in one of them at Kafr Hassan Saad in Qaliubia in 1938 where this was more satisfactory, although possibly not at the optimum. were as follows :—

(*Kantars per Feddan*)

		0N	1N	2N	3N	4N	Mean
0P	Dibble-sowing ...	6·35	7·22	7·56	8·08	8·30	7·50
	Ordinary sowing ...	5·18	6·34	6·86	7·64	7·60	6·72
2P	Dibble-sowing ...	6·24	6·37	7·32	7·62	6·98	6·91
	Ordinary sowing ...	5·26	7·45	7·15	7·68	7·81	7·07
	Mean	5·76	6·85	7·22	7·76	7·67	—

S.E.=0·21

The object of dibble-sowing is to have as many of the plants as possible in the best condition so that their growth performance will be superior ; the consistent increase in yield from dibble-sowing without superphosphate shows that this has been achieved. In the presence of superphosphate the advantage is maintained only so long as no nitrogen is given ; when dibble-sowing nitrogen and superphosphate are combined the advantage from dibbling is trivial or may actually be reversed.

The direct effect of superphosphate, as well as its interaction with nitrogen, were not significant at Kafr Hassan Saad. Both effects were highly significant features of an experiment at Ayat (G za) in 1944 but, s the cotton in that experiment was all dibble-sown, they may have had essentially the same meaning as the second order interaction at Kafr Hassan Saad and have been in reality an expression

(1) These are more fully discussed in "*Dibble-Sowing of Cotton, Method, Effects and Profi s*", by W. L. Ball and D. S. Gracie. Bulletin No. 229. Technical and Scientific Service, Ministry of Agriculture, Egypt (1939).

of the combined effect of sowing method, phosphate and nitrogen, especially as the direct (depressant) effect of superphosphate is insignificant when its interaction with nitrogen is taken as error :—

1944 Experiment at Ayat (Giza)

(kantars per feddan)

	0N	1N	2N	3N	4N	
0P	5·73	7·60	8·23	8·72	8·97	
2P	5·69	7·56	7·34	7·41	7·51	S.E. = 0·19

It has already been mentioned that in some of the exceptional experiments in the series including a comparison between dibble-sowing and ordinary sowing an unsuitable time-scale for the watering intervals may have influenced the result. Even in the more satisfactory conditions of the Kafr Hassan Saad experiment the total interval between the sowing and second waterings was sixty-nine days so that although a " light " watering is recorded as having been given betwe n the sowing and the first waterings the dibble-sown plants manured with superphosphate and nitrate may have suffered from w ter-strain, since it is not possible to define exactly what is meant by the term " light ". At Ayat in 1944 the two-watering interval was fifty-two days which would mean (Fig. 4) that the full benefit from dibble-sowing may not have been obtained even in the absence of phosphate.

For the whole period of fourteen years (Table 18) there are seventeen experiments in which significant depressions were occasioned either from the direct effect of superphosphate or from its interaction with the nitrogen supplied or from both. Thirteen of the seventeen were in Upper Egypt. In two the watering practice was not recorded and of the remaining fifteen eleven had a two-watering interval of fifty days or more so that the cotton in them may have been more or less water-short.

It is concluded that the rare cases of depression from superphosphate tend to occur on good soils in the warmer parts of Egypt where nitrogen is ample but where the water supplied is inadequate to maintain the further growth occasioned when superphosphate is added.

Practical Application

All of the foregoing has a very practical application which is best brought out by the straightforward grouping of the individual experiments according to control plot yield regardless of season, treating of Upper Egypt separately from the Delta. The total increases in yield over these control plot yields at each level of nitrogen have been averaged for the experiments in each group. The result of the grouping is given in Table 22 and illustrated in Fig. 16:—

TABLE 22.—CLASSIFICATION OF EXPERIMENTS ACCORDING TO LEVEL OF YIELD AND THE AVERAGE RESPONSE AT THESE LEVELS

(Kantars per feddan)

Experiments with control plot lying between:	Number of experiments	Per cent of total	Average total increases over control plot yield in moving from: 0–1N	0–2N	0–3N	Average total production
			Delta			
1– 2	3	0·9	0·37	0·71	0·98	2·48
2– 3	14	4·4	0·60	0·89	1·10	3·60
3– 4	37	11·6	0·67	1·03	1·24	4·74
4– 5	73	22·9	0·61	1·02	1·29	5·79
5– 6	80	25·1	0·83	1·38	1·72	7·22
6– 7	49	15·4	0·89	1·39	1·65	8·15
7– 8	43	13·5	0·83	1·29	1·53	9·03
8– 9	15	4·7	0·80	1·21	1·33	9·83
9–10	2	0·6	0·48	0·71	0·50	
10–11	3	0·9				
	319	100·0				
			Upper Egypt			
1–2	1	0·6				
2–3	5	2·9	1·33	2·19	2·55	5·08
3–4	23	13·4	1·03	1·77	2·11	5·61
4–5	32	18·6	1·29	2·03	2·49	6·99
5–6	32	18·6	1·07	1·59	1·98	7·48
6–7	31	18·0	1·01	1·62	1·90	8·60
7–8	23	13·4	0·87	1·23	1·69	9·19
8–9	11	6·4	1·00	1·46	1·84	10·34
9–10	10	5·8	1·13	1·29	1·36	10·86
10+	4	2·3	1·09	1·82	2·00	12·50+
	172	100·0				

In Fig 16 *b* for the Delta the average total increases at each level of nitrogen have been plotted against the control plot group with which they are associated and the points joined up. The efficiency of a given amount of nitrogen abruptly rises to a maximum with control plot yields of between five and six kantars, the disparity with yield levels lower than this increasing with the amount of nitrogen given. Efficiency is maintained at the maximum on six kantar land and then decreases as the available soil nitrogen becomes more adequate, but it remains substantially greater than on four kantar land until the five experiments with control plot yields of nine kantars or more are reached, when it again becomes very low. The response curves of Fig 16 *c* are another way of showing the same differences in efficiency; the return from the first application of nitrogen on land already yielding five kantars or more is greater than on lower yielding land and the subsequent steeper slope of the curve means that the advantage steadily increases as more nitrogen is given.

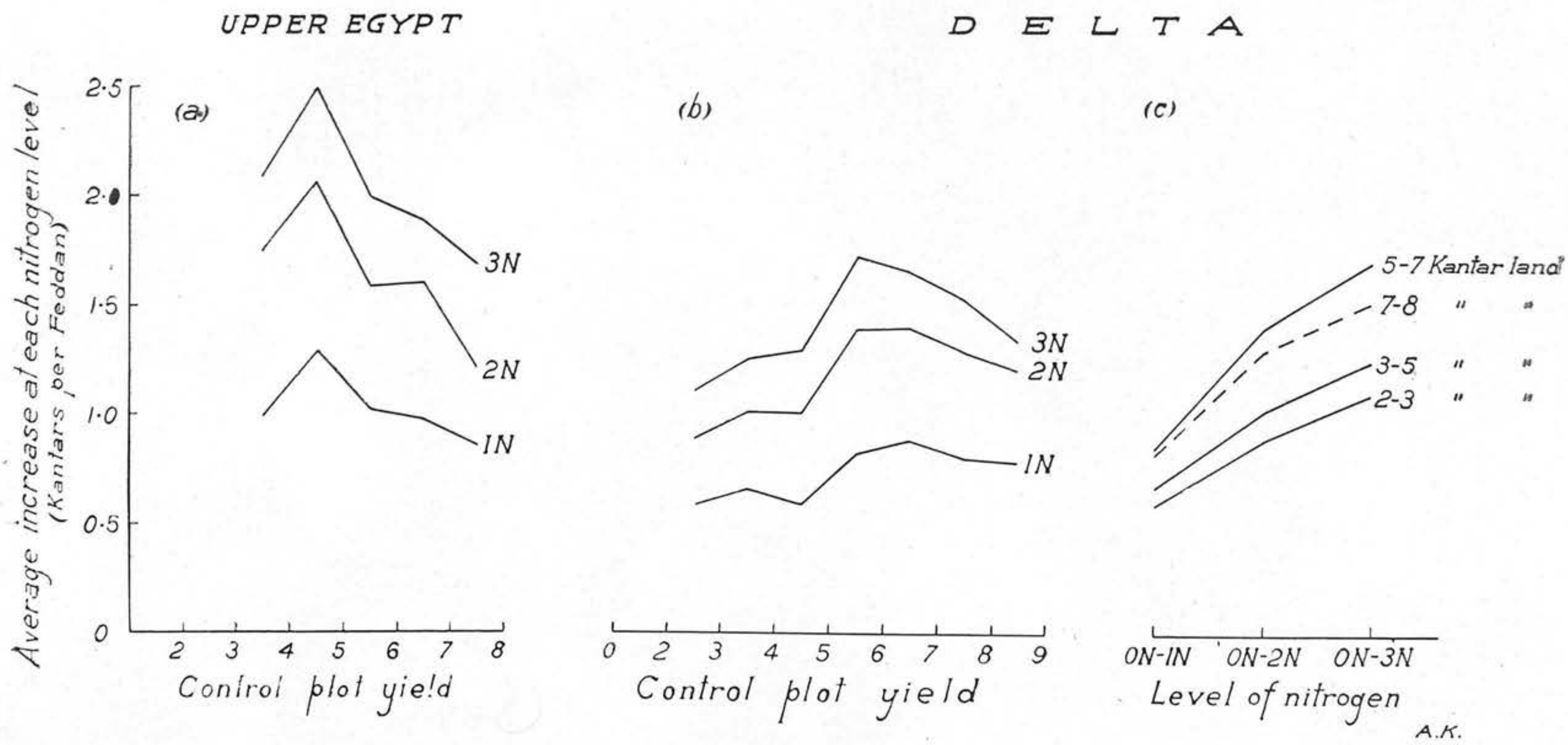
In Upper Egypt the return from a given amount of fertiliser nitrogen is always greater on the whole than what is found in the Delta; maximum efficiency is reached at the lower level of four kantars but thereafter the efficiency of the two higher applications immediately falls below even what is obtained on three kantar land and continues to drop —thus recalling the fact that yields in Upper Egypt are less dependent than in the Delta on picking the late bolls. This decrease in efficiency does not apply to the first hundred kilos which mainly influence the number of bolls lower down on the plant and the return from which, if seven-kantar land be excepted, is relatively stable for all groups at one kantar or more.

Importance of Level of Yield

It is, however, the figures for total production in Table 22 that provide the fundamental feature of the results in both regions. They show that it is the control plot yield that dominates the situation; once it is fixed, whatever may happen in an individual experiment, no amount of manure can in general alter it and convert, for example, a four kantar crop to one of five kantars or one of eight kantars to one of nine. Nitrogen, whether already available in the soil or added as fertiliser, can in general only act within the limits imposed by the factors determining the level of yield. In the Delta, once these can be adjusted to give a control plot yield of five kantars or more, increased efficiency of fertiliser nitrogen follows as a matter of course, but the actual level to which they have been adjusted continues to dominate the result.

Fig.16

RELATIONSHIP BETWEEN LEVEL OF YIELD AND RESPONSE TO NITROGEN



Factors Determining the Level of Yield

The factors determining the level of yield are irrigation practice in conjunction with the physical properties of the soil (which determine the water intake of the root system), locality, sowing date, spacing and the previous crop and above all the nature of the season ; variety is regarded as an expression of locality. The immediate interest here is in sowing date, locality and the previous crop. Maintaining the control plot g ouping of Table 22 the Delta experiments have therefore been split up according to whether they come after berseem, after rice or after other crops (chiefly maize) and the experiments in the last category again into those respectively north and south of latitude 31′ 00° (*i.e.* of a line passing roughly through Damanhour and Mansoura). For each of the four subdivisions so obtained the average sowing date, and its range, and the average total increases from nitrogen have been calculated for the experiments in the different control plot groups. The experiments in Upper Egypt can be usefully subdivided only according to whether they are after berseem or after maize and other crops. The result is given in Table 23.

TABLE 23.—AVERAGE RESPONSE TO NITROGEN ACCORDING TO LEVEL OF YIELD AS DETERMINED BY LOCALITY, SOWING DATE AND THE PREVIOUS CROP. *(Kantars per Feddan)*

Control plot yields lying between :	Number of experiments	Average total increases over control plot yields in moving from			Average sowing date (March)	Range of sowing date
		0 – 1N	0 – 2N	0 – 3N		
***Delta Experiments North of Latitude* 31°00′ (*mainly after maize*)**						
2–3	3	0·64	0·82	0·84	18th	7/3– 2/4
3–4	11	0·55	0·86	0·90	17th	7/3–23/3
4–5	12	0·29	0·65	0·79	13th	28/2–24-3
5–6	12	0·74	1·07	1·39	16th	7/3–24/3
6–7	6	0·83	1·43	1·76	8th	25/2–19/3
7–8	9	0·74	1·01	1·32	12th	27/2–27/3
8–9	1	1·56	2·89	3·11	18th	—
***Delta Experiments South of Latitude* 31°00′ (*mainly after maize*)**						
2–3	3	0·80	1·43	2·08	15th	—
3–4	7	0·89	1·41	1·72	9th	26/2–22/3
4–5	23	0·57	0·89	1·09	9th	22/2–18/3
5–6	42	0·87	1·49	1·83	6th	15/2–26/3
6–7	29	0·94	1·40	1·66	3nd	21/2–27/3
7–8	21	1·08	1·63	1·93	2nd	19/2–21-3
8–9	9	0·91	1·19	1·32	2nd	19/2–11/3
9–10	1	—0·15	+0·39	—0·10	4th	—
10–11	2	0·92	0·96	0·75	5th	—

TABLE 23 (*contd.*)

Control plot yields lying between :	Number of experi-ments	Average total increases over control plot yields in moving from :			Average sowing date (March)	Range of sowing date
		0 – 1N	0 – 2N	0 – 3N		
For Experiments in Upper Egypt (mainly after Maize)						
3– 4	22	1·05	1·81	2·17	5th	11/2–28/3
4– 5	23	1·13	1·91	2·28	1st	17/2–11/3
5– 6	26	1·18	1·61	2·01	1st	15/2–20/3
6– 7	25	1·11	1·74	2·07	3rd	13/2–22/3
7– 8	17	0·84	1·24	1·71	3rd	15/2–19/4
8– 9	11	1·00	1·46	1·84	1st	17/2–17/3
9–10	9	1·21	1·27	1·32	1st	22/2–12/3
10+	3	1·13	1·69	1·78	23rd Feb.	—
For Delta Experiments after Berseem						
1– 2	2	0·42	0.71	0·92	26th	—
2– 3	1	—	—	—	—	—
3– 4	9	0·63	1.07	1·32	14th	29/2–28/3
4– 5	20	0·68	1.11	1·40	22nd	5/3– 3/4
5– 6	14	0·74	1.18	1·51	12th	2/3–31/3
6– 7	10	0·76	1.21	1·53	12th	28/2–28/3
7– 8	10	0·59	1.15	1·41	10th	1/3–20/3
8– 9	4	0·32	0.82	0·83	10th	3/3–21/3
9–10	1	0·02	0.34	0·14	24th Feb.	—
10+	1	0·70	0.92	0·98	5th	—
For Delta Experiments after Rice						
2– 3	7	0·48	0·70	0·74	18th	—
3– 4	10	0·69	0·92	1·19	13th	—
4– 5	18	0·79	1·34	1·72	14th	—
5– 6	12	0·87	1·54	1·93	15th	—
6– 7	4	0·90	1·70	1·80	17th	—
7– 8	3	0·15	0·24	—	5th	—
8– 9	1	0·94	1·37	1·64	23rd	—
For Experiments in Upper Egypt after Berseem						
3– 4	1	0·56	0·87	0·86	30th	
4– 5	9	1·69	2·34	3·01	11th	26/2–4/4
5– 6	6	0·56	1·49	1·85	9th	2/3–18/3
6– 7	6	0·58	1·14	1·17	12th	26/2–27/3
7– 8	6	0·96	1·20	1·63	10th	23/2–29/3
8– 9	0	—	—	—	—	—
9–10	1	0·40	1·44	1·73	27th	—
10+	1	0·98	2·19	2·65	20th Feb.	—

Influence of Sowing Date

Nothing could be clearer than the influence of sowing date in the *Delta* shown in the table. South of latitude 31° 00′, where early sowings are more generally possible, three-quarters of the experiments have control plot yields of five kantars or more ; for the later-sown experiments in the north and after berseem the number at these higher levels decreases to roughly one-half of the total, while they constitute a third only of the still later-sown experiments after rice, although it will be remembered that the lowered available soil nitrogen after rice contributes to this result. In the same way within each series of experiments, with the exception of those after rice, progressive increase in level of yield goes hand in hand with increased earliness in sowing, the association being most pronounced in the southern region where really early sowing is more often possible and the proportion of high-yielding experiments consequently greatest.

The early average sowing dates of the more favourable growing seasons of *Upper Egypt* show no such general association with the yield levels, although it is probably significant that the highest yields are the result of February sowings. The average sowing dates in the experiments after berseem are again consistently later than for the experiments after maize.

It should be noted that the later average sowing dates in the experiments after berseem are not due to exceptional lateness in a few but are the result of a real shift in time of the whole body of experiments conducted after the crop similar to what happens in moving from Upper Egypt to Lower Egypt or from the southern to the northern half of the Delta.

Efficiency of Nitrogen in Relation to Locality, Level of Yield, Sowing Date and the Previous Crop

The pattern of response shown in Fig 16 *b* is repeated in all subdivisions of the *Delta* experiments with the efficiency of fertiliser nitrogen rising to a maximum when control plot yields of five kantars or more are reached. The actual amount of benefit at any given level is at the same time always less in the north than in the south, in agreement with the later average sowing dates of the cooler region. This is in harmony with the " normal " expectation in the Delta already demonstrated from the individual experiments within years, viz, that control plot yield and maximum increase will be negatively associated with sowing date so that both yield and benefit will increase together, but the amount of benefit possible depends on the actual temperatures experienced as well as on the extent to which advantage is taken of them, as represented by the sowing date.

The Delta experiments after berseem, seventy-two in number, and distributed as to thirty north of latitude 31° 00′ and forty-two south of it, have average sowing dates more closely approaching those of the former region. The average response is accordingly similar to what is found in the north except for the somewhat greater efficiency of nitrogen with control plot yields of three and four kantars.

The efficiency of nitrogen on cotton grown after rice, on the other hand, is if anything, even higher than what is found in the southern Delta. This is in compensation for the reduced control plot yields associated with the lower soluble nitrogen present in the soils at thinning (*see* above under "Available Soil Nitrogen") ; without this special circumstance, response to nitrogen would be much lower and similar to what is recorded in the north or after berseem since the experiments after rice are almost equally divided between north and south and have the latest average sowing dates. The abnormally high return from nitrogen at the two lowest control plot groups in the experiments south of latitude 31°00′ is also to be attributed to deficiency in available soil nitrogen.

The late sowing of the experiments after berseem in *Upper Egypt* has also resulted in their case in a diminished response to nitrogen with the outstanding exception of the nine at the four-kantar level where the average benefit is higher than is recorded for any other group. Their separation from the main body of the experiments considerably modifies the picture for Upper Egypt given in Table 22 ; the efficiency of nitrogen at the five, six and seven kantar levels is increased and that at the four-kantar level is much reduced although it still maintains its superiority over the others. Two kantars or more are obtained from three sacks up to and including the six-kantar level and the average return from one sack is never less than one kantar except with the control plot group at seven kantars ; if the nine experiments after berseem on four-kantar land are disregarded these are the highest average responses shown in Table 23.

Apart from the lowered response associated with the late sowing of some of the experiments after berseem, there is no connection between the yield figures and average sowing dates for Upper Egypt in Table 23. It will not be forgotten however that, from a seasonal point of view, earliness in sowing has been shown to have considerable influence.

Average sowing dates then become (Fig. 8) negatively correlated with average control plot yield [1] and in individual experiments within years there is equally a consistent emphasis on earliness in sowing for response to manure. As a result average control plot yield and benefit from nitrogen tend to go together although not in so marked a manner as they do in the more limiting conditions of the Delta.

Seasonal Variation in General

From the locality or climatic point of view one can therefore move in the cotton growing area from the south, where no one would willingly grow the crop w thout an adequate supply of nitrogenous fertiliser, to low-yielding land in the north where its use is inadvisable. The effect of the season is over iding; from this cause alone, neglecting other factors altogether, only one experiment out of the twenty conducted in the Delta in the favourable season of 1937 had a control plot yield of less than five kantars whereas following on the cold spring of the succeeding year only twelve out of twenty-one experiments had a control plot yield above that figure; and as the average maximum benefit from nitrogen increases with control plot yield, it was correspondingly greater in the more favourable season at 2·66 kantars in 1937 as against 1·22 kantars in 1938. It is equally important to realise the implications of long term alterations in climate similar to the geographic alterations encountered in moving between north and south in the cotton growing area. Such a long period change to higher temperatures occurred during the thirty-five years from 1904 to 1940.

In Fig. 17 are shown the five-year running averages through the montl ly mean of day (true mean) temperatures at Helwan Observatory for the first seven months of t e year for the years 1904–1940. These show that the period during which the experiments were conducted was also on the whole a period of high or rising temperature. Prior to 1914 the opinion was expressed that the nitrogenous manuring cf cotton in the Delta did not pay [2] which was certainly not the case in most of the years during which the experiments have been running. The difference between the low temperatures in March, which were normal when that opinion was formed, and those which happened regularly in 1931–1940, is very striking. The conclusions

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(1) The late-sown experiments after berseem in Upper Egypt are rather unequally distributed in time (*see* Table 7) but the value of the association between average sowing date and average control plot yield is little affected if they are excluded from the averages.

(2) F. Hughes, Year Book of the Khedivial Agricultural Society, p. 159 (1909).
J. A. Prescott, Bulletin No. 13 of the Sultanic Agricultural Society, p. 47 (1924).

to be drawn from it would be quite definite were it not for the measures introduced after 1912 to minimise the effect of the pink bollworm. As is well known these include changes in methods of cultivation such as closer spacing and the growing of earlier and higher-yielding varieties; and this necessity for an earlier crop may have created a permanent need for additional nitrogen quite apart from temperature considerations. With this reservation it is evident that the sixteen years during which the effect of nitrogen has been investigated occurred in a period when temperatures happened to be such as to favour benefit from its use. When the temperatures fall again opinion as to its utility will equally undergo revision. Long-term seasonal variation of this kind naturally affects cotton in the Delta much more than that grown in Upper Egypt where, with a warmer climate, nitrogenous manuring will always be useful.

Conclusions

It follows from the foregoing analysis that the only practical steps that can be taken, regarding the country as a whole, to increase the efficiency of nitrogenous fertilisers must be directed towards raising the general yield level to the extent permitted of by locality and season. Unfavourable seasons cannot be avoided but a great deal can still be done to mitigate their effects. The main concern must always be to increase the number of early bolls. Yield effects from late bolls are limited and uncertain; in Upper Egypt they largely depend on what the temperatures in April have been and in the Delta are a pure speculation on what the weather in August and late July will be like.

The maximum production recorded is in Upper Egypt where thirteen kantars per feddan have been obtained in four experiments and where yields of ten kantars or more have been common. Such high yields as these last are not so frequently possible in Lower Egypt; the maximum there is represented by the twelve kantars obtained in one experiment with Karnak in 1944 and there are only seven experiments in which the yield has been more than eleven kantars. These desirable yields include the effect of added nitrogen, but they are essentially the end result of the suitable adjustment of the factors of irrigation practice and spacing combined with early sowing on good soils in favourable seasons.

In the period covered by the experiments the movement towards closer spacing (and the consequent improvement in yields) has been noted, but the country as a whole has not gone far enough in that direction, or at least had not done so by 1940 when the last counts were made. It possibly never will, since impracticably close

MEAN OF DAY TEMPERATURE (°C)
HELWAN 1904-1940

Fig. 17 Five year running averages through monthly means

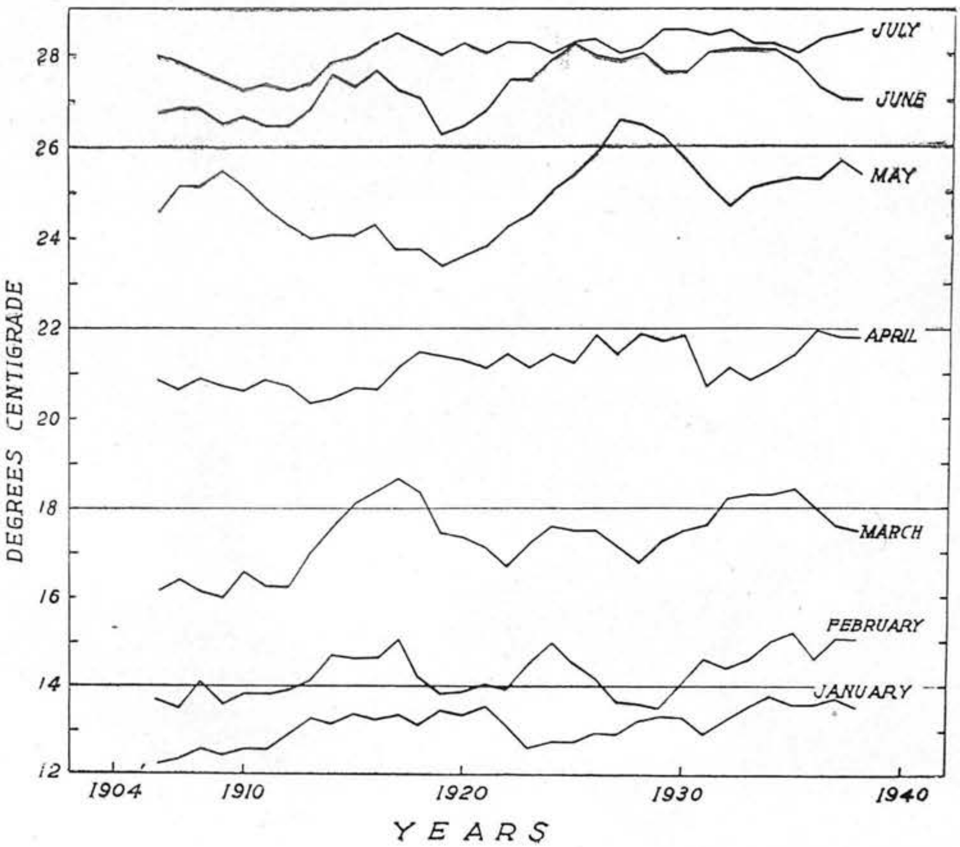
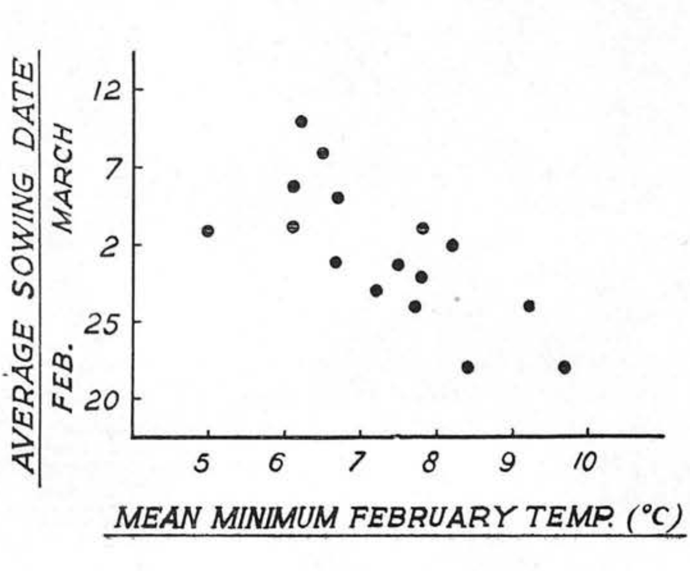


Fig. 18


AVERAGE SOWING DATE AND
FEBRUARY TEMPERATURES
IN UPPER EGYPT
(LEAVING OUT EXPERIMENTS
AFTER BERSEEM)
AVERAGE SOWING DATE
MARCH
FEB.
12
7
2
25
20
5
6
7
8
9
10
MEAN MINIMUM FEBRUARY TEMP. (°C)

ridging would be necessary to secure it, but the special necessity for the closest spacing in cold springs should not be forgotten. The position as regards irrigation practice is very similar. The time scale of the early waterings has always on the average been (variably and perhaps to some extent unavoidably) below the optimum and its importance has received its best illustration in the low temperature of the 1938 growing season, in relation to yield effects from dibble-sowing.

The connection between the average sowing dates employed in Upper Egypt and temper tures in February is shown in Fig 18. The limits to earliness in sowing are thus clearly set by locality and season and, while the highest yields cannot be obtained without it, too early sowing in an unsuitable season will result in serious loss if only from the amount of resowing it entails. The penalty that must equally be paid if cotton is late-sown is well brought out by the inferior average result obtained in the experiments after catch crop berseem. The highest yields can be obtained after berseem if the cotton is reasonably early sown (Table 23) and the problem with late sowing after the catch crop is quite simply whether the value of the fodder gained offsets the loss that is certain to be incurred. A comparison of the sowing date ranges in these experiments after berseem with those in the experiments after maize shows that while the upper limits are distinctly later the lower limits are substantially the same. This means that there is considerable room for improvement in the optimum adjustment of sowing date with all groups of experiments. Assistance in this could be obtained from dibble-sowing since the amount of resowing necessary is always significantly less where this method has been efficiently carried out. The difficulty with it is the extra labour involved, but it has been suggested that this could be largely overcome by delinting the seed and using a semi-automatic dibble (1). It should be clearly understood at the same time that the use of the method will not alter the optimum sowing date.

The comparison in Figs 2*a* and 2*b* of the average yields in the experiments (which include the effect of 3N) with the average for the whole country shows that they run at a much higher level. To the extent that this is due to the experiments being carried out on land better than the average it would necessitate the scaling down of the level of yield. This would in turn involve a scaling down of the benefit in so far as the Delta is concerned but would not affect the estimate of the return from nitrogen in Upper Egypt, which might even be

(1) *Dibble-Sowing of Cotton, Method, Effects and Profits*", by W. L. Balls and D. S. Gracie, Technical Bulletin No. 229, Ministry of Agriculture, Egypt (1939).

slightly increased, since it is at a maximum on four-kantar land (Table 23). In a recent appraisement [1] of the statistics for agricultural yield in the country it was calculated that the cotton area in Upper Egypt must have been receiving nitrogenous fertiliser at the rate of 3N (the equivalent of two kantars in the average yield) at least as early as 1935 and may subsequently have been getting rather more ; the rate of application to Delta cotton as a whole is more uncertain but it had reached an average of at least 1N ($15\frac{1}{2}$ kilos of nitrogen per feddan) by 1935. The uncertainty about the amount going to Delta cotton arises partly because it is very far from being evenly distributed since the use of artificial nitrogen would begin in the south, where the largest return is obtained from it, and gradually sp ead northwards ; low-yielding land in the north is unlikely ever to have received very much at all. From the seasonal point of view the most disconcerting swings in yields (and therefore including return from manure) occur on the inferior or deteriorated soils. Such soils are of more frequent occurrence in the north where the expectation from fertiliser nitrogen for climatic reasons even on normal soils is in any case least. The question of increasing the efficiency of ertiliser nitrogen in the Delta is therefore bound up with the general qu stion of the prevention and remedying of soil deterioration. As things are, ca ef l attention to the proper adjustment of the other factors determining yield level such as irrigation practice, spacing, sowing date and method is especially important for su cess on deteriorated soils (as it is in unfavourable seasons) while in the perverse nature of things they are least likely to receive it.

Summary

The results of 491 experiments on the effect of nitrogen and superphosphate on the yield of cotton carried out during the sixteen years from 1931 to 1946 are analysed.

The manurial treatments apart, the instructions were that the practice of the farm on which an experiment was carried out should not be altered but that the details of the practice should be recorded. The experiments were well distributed throughout the country and their results are shown to be a reasonable reflection of what happens in ordinary cultivation.

The effect of fertiliser nitrogen is distinguished according to whether it increases the early or the late bolls.

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(1) "*Evaluating the Effect of Nitrogenous Fertilisers by Combining Statistical and Agronomic Data*", by W. L. Balls, D. S. Gracie and F. Khalil, Technical Bulletin No. 249 Ministry of Agriculture, Egypt (1948).

The desirable thing is to increase the *early bolls.* The extent to which this is possible depends on the temperatures experienced in the early part of the growing season and the advantage that is taken of them, as represented by the sowing date.

There is a well marked optimum sowing date which becomes steadily earlier as one moves from north to south but which at any one locality varies from year to year according to temperature.

The "normal" expectation in *individual* experiments in the *Delta* is that yield without manure and benefit from its use will be greater the earlier the crop can be sown so that both will increase and decrease together, with the actual possibilities being decided by the nature of the season. The emphasis of earliness in sowing for control plot yield is always maintained but the "normal" expectation as regards increase from nitrogen may be upset, for example, if the weather in May is unsuitable or if the available nitrogen in the soil is unsually low.

In the more favourable growing temperatures of *Upper Egypt*, more stimulation of early boll production by nitrogen is possible in any year. Control plot yields in *individual* experiments are comparatively indifferent to the dates on which they are sown but the efficiency of fertiliser nitrogen is consistently greater where the crop is early sown and where control plot yield has been limited because of low available nitrogen in the soil.

When average *differences between years* are considered the emphasis of sowing date in the two regions is reversed and earliness in sowing becomes most important for control plot yield in Upper Egypt and for increase from nitrogen in the Delta. In both regions the higher the level of yield (control plot yield) the greater is the response to manure, the relationship being strongest in the Delta, with its more limited growing conditions.

The extent to which *late bolls* are picked in the Delta depends on the degree of heat they encounter in August and late July, ex essive heat causing undue shedding. By comparison any summer in Upper Egypt is hot, fewer late bolls on the whole are picked and the extent to which this does happen depends on April temperatures; where these have been low growth tends to be prolonged.

From the *locality* point of view the efficiency of a given amount of fertiliser nitrogen is greatest in Upper Egypt; the average response curves show the advantage there over the Delta to be a quarter of a kantar at 1N (15 $\frac{1}{2}$ kilos of nitrogen) increasing to half a kantar at 3N. In the Delta itself both yield without manure and benefit from its use increase from north to south.

Variety is regarded as an expression of locality.

The available nitrogen present in the soil at the time of sowing has no meaning for the recorded yields, but the " soluble " nitrogen in soil samples taken at thinning (about a month and a half later) is positively related to the control plot yields and the " hydrolysable " nitrogen negatively with maximum increase from nitrogen, the former relationship being the more pronouncecd The continuous variation in the state of the organic matter and nitrogen present is discussed ; the average amount of "soluble" nitrogen present in the soils at thinning for example, is shown to be a function of the temperatures in April, being high where these have been low. The soils of the experiments conducted after rice are distinctly lower in soluble nitrogen than the average and the response to fertiliser nitrogen disproportionately high as a result. It is suggested that, where the available nitrogen in the soil can be expected to be low the application of a portion of the nitrogenous fertiliser earlier than at thinning might be useful.

The average direct effect of superphosphate on yield is 0·18 of a kantar per feddan and significant response has occurred in about one in four of the experiments ; it only occurs where the available phosphoric acid (Aspergillus niger test) sinks below a certain minimum value somewhere in the subsoil, although it is not necessarily obtained when this happens. Interaction with nitrogen, meaning that the efficiency of the larger dressings is increased, becomes notable as the direct effect increases. The subsoils of perennial land are being progressively exhausted of available phosphoric acid so that the need for superphosphate must be expected to increase. As regards variation in temperature. superphosphate acts in a manner contrary to that of nitrogen positive effects tending to be greater in cold (April) weather while (rare) depressions may result from its use where temperature and nitrogen supply combine to favour rapid vegetative growth and where the water supplied is possibly inadequate.

For the demonstration of the practical meaning of the results seasonal effect is disregarded. The experiments in Upper Egypt are subdivided according to whether they come after berseem or after other crops (chiefly maize) and the Delta experiments into those respectively after berseem, rice and maize and the ones after maize again according as they are north or south of latitude 31°00′. The experiments in each subdivision are then grouped according to control plot yield and the sowing dates and increases from nitrogen averaged for each group.

In the Delta, the experiments after rice excepted, increase in control plot yield is then associated with increased earliness in sowing. The same pattern of response is repeated, with variations, in each of the subdivisions with the efficiency of fertiliser nitrogen increasing to a maximum when control plot yields of five kantars or more are reached. The actual amount of benefit at any given level of yield is always less in the north than in the south in agreement with the later average sowing dates of the cooler region. Response in the experiments after rice is greater than would be expected from locality and sowing date because the soils are poorer in soluble nitrogen than the average. In the experiments after berseem, on the other hand, response is less than would be expected from the locality distribution because of delayed sowing.

The early average sowing dates of the groups of experiments after maize in Upper Egypt do not show the general correspondence with control plot yield that is found in the Delta. The efficiency of nitrogen is at its maximum on four kantar land but two kantars or more are obtained from 3N up to and including the six kantar level and the average return from 1N at all levels, with one exception, is never less than one kantar. The average sowing dates in the experiments after berseem are again consistently later than in those after maize and have again resulted in a diminished response to nitrogen with the outstanding exception of the nine at the four-kantar level where the average response is higher than for any other group.

The most fundamental feature of the results in both regions is found in the fact that control plot yield (level of yield) dominates the situation ; once it is fixed no amount of manure can in general alter it and raise, for example, a four-kantar crop to the five-kantar level. The constant aim of the grower must be to raise the yield level ; in the Delta once it can be adjusted to five kantars or more increased efficiency of fertiliser nitrogen follows as a matter of course.

The factors determining the yield level, in addition to locality (latitude) and sowing date, are the physical properties of the soil, spacing and irrigation and above all the nature of the season ; the available nitrogen in the soil is rarely limiting in the same sense. The nature of the season cannot be altered but a review of the practice in the experiments as regards spacing and irrigation shows that there is room for improvement and that their proper adjustment is of special importance in unfavourable seasons. The most disconcerting swings in yield from a seasonal point of view occur on deteriorated soils, i.e. soils whose physical properties have been adversely affected. This will again apply more particularly to the northern region where such soils are in any case of more frequent occurrence. From a long-period point of view the maintenance and raising of the level of yield will depend on the prevention and remedying of soil deterioration. The maximum yield (including the effect of fertiliser nitrogen) recorded in the experiments is represented by the thirteen kantars per feddan obtained in four experiments in Upper Egypt ; maximum yield in the Delta is lower.

It is important to realise the implications of long-term alterations in climate similar to the geographic alterations encountered in moving between north and south in the cotton-growing area. The experiments were carried out during a period of high temperatures which favour benefit from the use of nitrogen. When temperatures fall again opinion as to the utility of nitrogenous fertilisers will equally undergo revision.

Acknowledgements

The field experiments were conducted after 1940 by the Field Experiments Section and before then by the Agronomic Section. In their analysis we have had the assistance of Mohammed El Kadi, Ahmed El Shabassi and Mohammed Abou el-Fadl of the Chemical Section.

The estimations of available soil nitrogen were mainly carried out by Mohammed El-Kadi and Ahmed El Shabassi.

Govt. Press 15097-1948-500 ex.